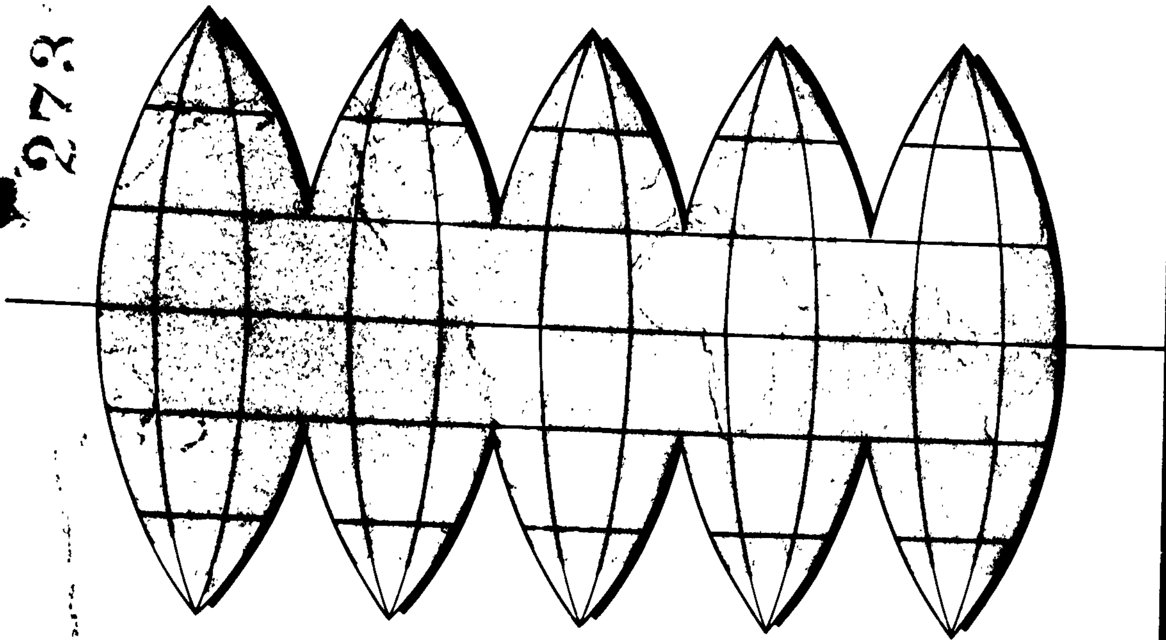


UNICOM

BELL SYSTEM

ITT

RCA

UNICOM UNIVERSAL INTEGRATED COMMUNICATION SYSTEM

PROGRESS REPORT FOR THE
TENTH QUARTER
1 OCTOBER THROUGH 31 DECEMBER 1961

VOLUME II

REPORT NO. 10

THE OBJECTIVES OF THIS CONTRACT ARE TO DEVELOP SYSTEMS ENGINEERING PLANS FOR A PROTOTYPE OF THE UNIVERSAL INTEGRATED COMMUNICATION (UNICOM) SYSTEM AND TO PROVIDE AND TEST A SKELETONIZED ENGINEERING MODEL (PRELIMINARY TYPE) OF THE SYSTEM

APPENDICES

FIGURES

PART III
APPENDICES

Appendix 3A

MAINTENANCE AND RELIABILITY GUIDELINE FOR UNICOM

D. R. Barney, G. F. Clement, C. W. Haas,
and R. L. Simms, Jr.

The material contained in this appendix furnishes a guideline for reliability and maintainability of UNICOM and presents some desirable objectives in these areas. It contains definitions of reliability, maintainability, system down time, station down time, error, fault, etc., as they apply to UNICOM. It presents objectives for reliability, fault detection and diagnosis, and repair time. It points out the various factors to be considered in the design of the switching center equipment, including equipment design factors, program design factors, system design factors, and security aspects of maintenance.

DEFINITION OF TERMS

UNICOM System

For the purpose of this appendix the UNICOM system includes the equipment and programs used for both the operational and the maintenance functions. It does not include transmission media such as trunks, tropospheric scatter links, etc. All guidelines are to be observed at both the switching center and, where applicable, the subscriber stations.

Reliability

Reliability of an item is a measure of its ability to perform a specified function for a required period of time without a failure. The reliability of a system is expressed in terms of mean down time of the system per year.

Down Time

System Down Time. Down time may be defined in a number of ways. The entire UNICOM network is a system, each switching center is a system, and the switching center itself is composed of a number of subsystems. However, a common focal point for all of these is the individual subscriber. From his viewpoint, down time is that amount of time when he attempts or could attempt to make a call and because of an error or fault in that part of the UNICOM system beyond the output terminals of his station he:

(1) Receives either no response or a consistently incorrect response from the UNICOM system

(2) Consistently receives a response requesting the call to be placed again

(3) Would have encountered down time as defined in (1) and (2) above had he attempted to make a call.

System down time is obtained by first adding the total down time for each subscriber over a ten-year period and then dividing the sum by the total number of subscribers. By this definition a malfunction of the common equipment that would affect all subscribers for N minutes is scored as N minutes down time; a malfunction which affects L out of M total subscribers for N minutes is scored as (L/M)N minutes down time.

Station Down Time. Station down time is that amount of time when the subscriber is denied service owing to a malfunction in the station apparatus. This down time is measured over a ten-year period. Station down time is measured on a per-subscriber basis.

Maintenance

The maintenance of a system is defined as the process of detecting troubles in the system and repairing them.

Errors

An error is a malfunction which is not reproducible.

Faults

A fault is a malfunction of the system which can be reproduced. In practice, to classify a malfunction as a fault, we must define what is meant by "reproduced." For purposes of defining a fault, reproduced shall mean twice under the same circumstances. By this definition the first detectable symptom of a fault cannot be distinguished from an error without further analysis.

RELIABILITY OBJECTIVES

The very stringent reliability requirements for UNICOM can be seen from the following objectives.

Down Time

Each switching center must have essentially zero down time. Practically speaking, experience with complex electronic systems has shown that, using existing components and techniques, zero down time cannot be achieved. However, a practical objective is that the system down time shall not exceed 4 hours over the ten-year period.

Each station must also have essentially zero down time. A practical objective is that nonduplexed station down time shall not exceed 8 hours over the ten-year period. If a higher reliability is required at a particular station, it is recommended that the station and its lines to the switching center be duplicated.

High Grade of Service in Times of Stress

In addition, UNICOM has the requirement of being able to maintain a high grade of service in times of stress or degradation of the system. In short, UNICOM must be designed to operate during periods of stress because that is the time when it is probably needed the most.

Security

System failures should not compromise the security of calls in the system.

Call Handling

The number of calls handled incorrectly by switching centers should not exceed 0.1 percent of the total calls handled. None of this 0.1 percent shall compromise security on calls in the system.

Areas Affecting Reliability

(1) Design of the equipment and the programs that comprise the system such that the aggregate is inherently reliable and maintainable

(2) Introduction of redundancy into the system to enable it to perform satisfactorily even when failures occur.

MAINTENANCE OBJECTIVES

Since troubles in the system will occur, the objectives for maintenance are the following.

Signal Corps Maintainability Index

The system should be consistent with the Signal Corps Maintainability Index in those areas where it applies to UNICOM equipment.

Error and Fault Detection

Maintenance programs and hardware should be provided to allow the system to detect and analyze its errors and faults.

Repair Time

The maintenance facilities must provide for trouble location such that the mean repair time for a fault is much less than the expected interval between failures in the system. This time interval must be determined by an analysis of the hardware used. Preliminary results show that a mean repair time for a fault of 30 minutes may be adequate.

EQUIPMENT DESIGN FACTORS

A reliable system can be achieved only if the circuits themselves are intrinsically reliable. From the very beginning, the designer should consider reliability and maintainability as design parameters.

(1) Within economic reason, components with high inherent reliability should be used.

(2) Application of components should be such as to minimize their tendencies to fail. Suitable derating factors should be applied to each component.

(3) Worst-case circuit and logic design is mandatory.

(4) Failure of one component should not cause failures in other components. Wherever this is not possible, the spreading of failures should be confined to one plug-in circuit package.

(5) Failure of a component or shorting of any terminal to battery or ground should not cause a fire.

(6) Units duplicated for redundancy shall have separate trip-free circuit breakers and battery feed.

(7) Crosses between adjacent terminals should not cause component failures. This includes terminals so close together that crosses may easily be made by probes, clips, etc.

(8) Circuits should not be made so fancy that maintainability is impaired. This includes gross over-design beyond the normal circuit requirements.

Often the desired output can be obtained by using simpler circuits but a few more of them. This solution would often be preferred if the ease of maintenance and understanding were materially increased. The technique is to try to minimize circuit components without detracting from the ability to locate trouble in case of a failure.

(9) Functionally identical circuits should be fully interchangeable. There should be no need for adjustments at the time of installation or during service.

(10) Components should not fail because of a loss of one or more supply voltages or ground.

(11) Each subsystem should be designed in such a way that it cannot be damaged by other subsystems connected to it, providing the currents and voltages on the interconnecting cables are within specified limits. If a subsystem is given a contradictory set of inputs, or if its inputs are changed too frequently, it should not destroy itself.

(12) Packages should be easily accessible and replaceable. Plug-in packages should be used where technically and economically feasible.

(13) All designs shall be in accordance with prescribed design practices.

(14) The numbers of types of packages should be minimized. The introduction of any package not in accordance with prescribed design practices shall be subject to review.

(15) Packages should be designed with indicators and mechanical keying so that if they are plugged into the wrong socket neither the package nor the rest of the system is damaged.

(16) Plug-in packages should be able to withstand 1000 insertions and withdrawals from the connector. Connectors should tolerate 1000 insertions and withdrawals of the plug-in packages.

(17) Circuits must tolerate noise generated elsewhere in the system. Conversely, the circuits themselves should not contain sources of interference to other circuits. As more information becomes available, threshold noise limits will be specified.

(18) All apparatus must be designed such that security is preserved. This includes filtering of power leads, maintenance of proper slicing and regeneration levels, and the like.

(19) All equipment whose physical state must be represented by tables in the central processor memory should have a capability for program access to the true physical state so that registration can be assured between the true physical state of the equipment and its status represented in memory.

PROGRAM DESIGN FACTORS

It has not been widely appreciated in the past that specifying, designing, and writing programs requires engineering skill of the same caliber as required for circuit or system design. This fact is particularly true in a secure telephone and message communication and switching system like UNICOM. The programs must be written to give inherently reliable system operation just as hardware must be designed for inherently reliable circuit operation.

Programs are merely a serial set of logical steps to accomplish certain operations. In an idealized machine having no hardware troubles or environmental problems, the programs would be essentially self-contained and independent in a sense of the hardware. In any practical machine, the programs are less independent of the hardware, and this dependence must be considered in program design. The following paragraphs list such factors to be included in program specification and design:

(1) All UNICOM programs should be designed to facilitate understanding, debugging, modification, reliability, and maintenance. This rule means that the "brute force" approach to program design should be used as opposed to the very clever (but difficult to understand) techniques that save a few steps. In addition, this implies a requirement for the design of a utility system and assembler system which will provide facilities for debugging, modification, and maintenance and which will recognize in its design the permanent memory machine in which the programs must ultimately operate. Specifically, modification and maintenance of any specific subroutine in the system of programs should not require the generation of a complete new set of program store cards.

(2) Wherever possible, programs should be tolerant of hardware malfunctions and errors. They should be made failsafe in the sense that an error does not cause the system to lock up or loop. If this condition does occur, equipment timeouts must be provided to detect the fact.

(3) Where maps are kept of equipment states in memory, such as in recording of busy links or time slots in the switching matrices, all reasonable

methods of feedback should be employed to keep these in step. If possible, provision should be made to restore agreement between equipment states and memory automatically without affecting calls in progress when they disagree.

(4) In cases of ambiguity, programs must not make any assumptions that will compromise security. Stated more positively, the programs must contain safeguards to protect the security of all calls and messages.

(5) Communication between all operators in the system and the machine should be in a standard form easily understood by the operators.

(6) Programs should be as self-contained as possible. This implies that it is better to spend a few more program words to make the program self-sufficient than to rely on some certain hardware state or on another program to save those words.

(7) Defensive programming should be used whenever possible in those areas where hardware troubles can have a serious effect on service. For example, when establishing a connection in the space-division matrix, it is desirable to design the program so that an equipment error or fault does not cause a malfunction in the program.

(8) Maintenance programs should be designed such that they do not interfere with or destroy call maps or tables preserved in the call store by the operational program. This means maintenance routines requiring such facilities should use the subroutines normally used in the call processing program.

(9) All errors of a dynamic type detected by the call processing program in the course of its operation should be recorded with sufficient information to identify the error, its location, and to facilitate diagnosis.

(10) The maintenance program will be designed to make extensive use of prognostic tests during each portion of the call program cycle not used for the actual processing of calls. Prognostic tests are defined as tests for equipment malfunctions made at times when the equipments involved are not being used for call processing or associated UNICOM functional operations. The tests involve exercising idle equipment sequentially on a routine basis and searching for equipment malfunctions occurring during the exercise. Prognostic tests are made in an attempt to minimize the down time resulting from failure of the various equipments comprising the system.

(11) In a given equipment, i.e., time-division switch, vocoder, or modem, the detail to which troubles can be isolated by the maintenance program is limited by the test points to which the program has access. Hence, where practical, test points which are accessible to the program should be furnished [see (11) of Fault Location].

SYSTEM DESIGN FACTORS

One major consideration in system design is an optimum balance between the factors of interconnection of subsystems, switching, redundancy, and component reliability. The over-all reliability of the system, the economy of design, and the compatibility of subsystems are the main factors which influence the degree of redundancy, the organization of the subsystems, and the switching within the system.

Redundancy

Redundancy is an effective method of increasing the tolerance of the system to faults and thus the reliability of the system. Redundancy can be incorporated in a number of ways:

(1) Full duplication of a subsystem

(2) Partial duplication of a subsystem

   (a) One standby section per N active sections

   (b) Duplication of critical parts of subsystem only

(3) Inherent functional redundancy, such as the existence of multiple paths in the switching matrices from input to output

(4) Information handling in an error-detecting or correcting code

(5) Redundant circuits

(6) Redundant programs.

Switching of Redundant Equipments

When redundancy is used, there is usually some switching of units to be accomplished. The following list itemizes some requirements involved:

(1) Sufficient redundancy should be provided to permit meeting the system down time objectives discussed earlier in this appendix.

(2) All information contained in the call store and program store should be duplicated. One copy of the data should appear in the call and program stores associated with a given central processor and the other copy

should be in the call and program stores associated with the second processor. In addition, critical information in the call store should be duplicated within at least one call store memory associated with a given processor. This in effect provides three records of the critical information.

(3) Active and standby circuits must be sufficiently isolated so that a trouble in one does not impair the other. Also, if any matching circuits are used between them, a trouble there does not affect both sections.

(4) Physical arrangement of equipment and cabling should be such that simultaneous damage to duplicated units is very improbable if the system is subjected to physical damage, such as fire.

(5) One should be able to add, remove, or repair standby subsystems without interrupting service.

(6) Switching between redundant units shall be done at speeds comparable to the basic cycle time of the subsystem involved. For example, call stores should be switched electronically but space-division controllers may be switched at relay speeds.

(7) Effective means (such as removing the power from the cable pulsers) must be provided to prevent a unit from transmitting spurious pulses to other subsystems. Means must be provided to disable a malfunctioning unit when it may interfere with normal system operation.

(8) The inputs to and the outputs of a standby unit should be functionally and electrically equivalent to those of a unit in the active state.

(9) Interconnections between subsystems should be made in a uniform manner. For example, driving a cable and receiving information from a cable should use the same hardware everywhere in the switching center.

(10) Like pieces of equipment should be connected such that a common diagnostic routine is applicable to all. For example, if a tape control unit were used as part of a store and forward (S/F) module, it should be diagnosed with the same program that is used for the tape control for the switching center.

ERROR AND FAULT DETECTION AND DIAGNOSIS

The quality of service to the users of UNICOM is the prime consideration of the system. This includes maintaining service to the users and protecting the security of the information being carried by the system. In general, the user is completely disinterested in the errors and faults of the system. His main concern is with the call he is placing. For this reason, the following basic statement can be made regarding error and fault detection and diagnosis:

<u>Wherever there is a possibility of getting the call through, the diagnosis of the hardware should be considered secondary to serving the call.</u>

To explain the preceding remark, we must use certain criteria based on engineering judgment to decide whether the call should be abandoned or whether an attempt should be made to proceed. For example, if a connection attempt through the space-division matrix fails, it is reasonable to try again or shift to an alternate set of controllers. If these attempts fail, it is reasonable to make a new path hunt. However, if there is a central control fault which may have abused the information about a call, it is not reasonable to expect the call to be served properly with retrials. Between these two black and white cases lie a host of what might be termed "gray" situations which must be treated by the programmers on an individual basis. The following statement can be made for those cases that cannot be processed correctly:

<u>It is better to give the user re-order or an error signal than merely to abandon him.</u>

The system objective is that fewer than 0.1 percent of the calls will be handled incorrectly by the system and that none of these will compromise security. Because of the latter requirement, it is better to require the user to try again than to take the chance of violating system security.

Most faults will cause a discontinuity of service to at least some users unless the faulty unit is switched out of service rapidly. This, of course, requires that faults must be detected quickly and prevented from interfering with service. Errors, however, are of two types which must be handled in different manners. There are errors whose effects are transistory and errors whose effects persist over a long period of time. For example, if the system makes an error in recording a dialed digit, the call will be misrouted. However, if the user tries again, he will presumably be connected properly. On the other hand, if an error is made in recording a recent change to a user's line, from that time on all or many of the calls involving the user are likely to be handled incorrectly.

Error and Fault Detection

The system should have an ability to detect a fault in the active section before the fault can seriously affect the service or cause the loss of critical information. For example, a faulty central control can, if left in control of the system, seriously multilate the terminal map of a switching matrix within a few cycle times. Each standby section should be checked frequently to insure that it is operational and can function as the active unit in the event that the active unit fails. The mean down time of the system is a function of not only the basic subsystem reliability, amount of duplication, and repair time, but also a function of the frequency at which the standby equipment is checked.

When a section is duplicated, an advantage of the duplication can usually be taken by comparing the operation of the duplicated sections by matching. However, when a section fails, the matching ability is lost. The objective is to have a system which can operate in the presence of errors even when all standby sections are in trouble. This requirement implies that data be handled and transmitted in redundant codes or that the action taken is checked, using some type of feedback.

To be able to live with errors, it is not sufficient merely to detect them. When an error is detected, its perpetuation should be prevented and a wrong action that has already occurred should be corrected. Where feasible, facilities should be provided for retrial of the action which resulted in the error. Special care should be taken to detect and correct errors which have a lasting effect.

The system should be able to recognize when its operation is being hampered by errors; i.e., either program or circuit error rate indicators must be provided. Facilities should be provided to take clear snapshots of the situations under which the errors occur.

Fault Location

Fault location is imperative in a large, complex electronic system such as UNICOM. The following list contains desirable objectives for UNICOM.

(1) The system should be able to determine the faulty section in all cases of trouble.

(2) The system should be able to diagnose automatically more than 90 percent of the troubles that occur to within three or fewer circuit packages.

A circuit package in the central processor is interpreted as a logic card. However, dependent upon program accessibility to test points in an equipment such as the vocoder, the package may well be defined as the entire vocoder.

Every effort should be made to obtain identification of individual packages.

(3) Alarms and displays should be provided which will give the maintenance personnel an immediate visual indication of system status.

(4) The maintenance inputs and outputs should be simple and uniform. The system should print out only salient information. The maintenance man should be able to translate the outputs without voluminous dictionaries and without interpretation of complex patterns. He should be able to stop messages while they are being printed out and specify that only certain classes of messages be printed out.

(5) To supplement automatic diagnosis, it should be possible to operate one central control and associated memory off-line under control of the active units or the maintenance man.

(6) A system of program and hardware interlocks should be provided so that the maintenance personnel may not accidentally interfere with system operation.

(7) In the event that duplicate units appear to be in trouble simultaneously, the system should be able to judge which section is in better shape and then use that section.

(8) The maintenance man should be able to force the choice of active units by means not dependent on proper system operation.

(9) The diagnostic and other programs should not interfere with call handling. For example, switching of duplicate units which interrupt the system operation should be used only as a last resort.

(10) Diagnosis of any subsystem must be possible with the minimum hardware required to operate the system. For example, a single central processor, call store, and program store should be capable of diagnosing trouble in other subsystems.

(11) Matching circuits, parity check circuits, and scanner (ferrod) points may be used as tools in automatic maintenance. Therefore, in the design of a new piece of equipment a designer should, where feasible, provide computer access to test points introduced for his own unique circumstances.

(12) An economic balance between use of hardware and program for maintenance purposes is desirable.

(13) Equipment layouts should be made with the maintenance man in mind. For example, it is desirable to locate functionally related packages physically close together. Loss of some packing density may be worth it from the maintenance point of view.

(14) In those units where programmed diagnosis is impractical, suitable arrangements should be made for testing them off-line from a central location within the central office. For example, conversion devices might fall into this category.

(15) Marginal testing will be used in those cases when it may yield meaningful results such as in circuits having narrow margins or operating limits. However, it will not be considered a standard maintenance tool.

(16) The system should be able to detect fault situations that affect the real time occupancy of central control. For example, the inadvertent busying out of a trunk which indeed is not busy can seriously impair the ability of the central control to handle bonafide traffic. Design of the hardware and mode of operation should minimize the probability of failures of this type, but when they occur, the maintenance man should be able to rectify and remove the fault. [See (7) of Switching of Redundant Equipments.]

SECURITY

The involvement of maintenance with security brings up a multitude of problems. Because the very essence of maintenance implies the ability of a maintenance force to have access to all equipment in order to repair faults, this same ability gives the maintenance force access to certain classified material. For example, the maintenance man must have access to the temporary memories, which implies he can determine what conversations are present at any given time in the system. This must not constitute a breach of security. Since all the security aspects of the system have not been defined yet by specific requirements, the following assumptions will be made:

(1) It will be assumed that the maintenance man will have access to all units in the system for which he is responsible, unless specifically stated otherwise.

(2) Any units to which he does not have access will be considered unmaintainable by him, and if outputs of such units may cause errors in other sections or subsystems, those will likewise be unmaintainable to the degree affected by the error.

(3) The maintenance man shall be given the widest latitude in using the resources of the machine to maintain it.

As mentioned before, errors in the system shall not cause a breach of security. Likewise, hardware trouble should not be capable of compromising the security of the system.

Appendix 4A

TIME REQUIRED TO FRAME A LOG-DIFFERENTIAL PULSE CODE MODULATION SYSTEM

J. J. Horzepa

A differential pulse code modulation (PCM) system is one which samples the signal to be processed, codes the difference between the previous sample and the present one, and generates a multibit code representing this difference. The digital stream is then received and the signal recovered by a decoder which integrates the successive quantized difference signals.

UNICOM will use a differential PCM system for digitizing voice signals on 40.8-kbps digital lines. A nonlinear log scale will be used to code the difference samples. Contrary to normal PCM systems, the different quantum values represent the possible step sizes that can be utilized to represent the difference samples. Therefore, either large or small steps can be utilized at any point on the signal wave, rather than being restricted to particular amplitude regions. The largest step chosen will be one-quarter to one-third of the largest amplitude speech wave to be encoded. For zero input (no signal), the normal mode of the encoder will be for successive quantized values to oscillate between the smallest steps of +1 and -1. This will result in a low-level output at one-half the frame rate, or 4800 cps, which falls well outside of the normal speech band and can be eliminated by a low-pass filter. The decoding process requires the received digital signals to be reconverted to corresponding quantized values and applied to an integrator to recover the signals.

FRAMING

The method of framing the digital stream is based on the fact that the original speech input before encoding was bounded in amplitude with an average dc value of zero. Since the integrator at the decoder is being driven to follow the input signal, the integrator voltage will follow the same limited voltage pattern. If errors are made in the digital transmission, or if the decoder is out of frame, the integrator may exceed this upper bound.[1] If the decoder is out of frame, the words will be

[1] "Frame" here applies only to transmission between PCM terminals and is not related in any way to the framing used in UNICOM on digital lines and trunks.

scrambled and there will be parts of two original words in the frame. In order to prevent errors in transmission from causing the integrator to overload, a leakage path will be provided across the integrator. The time constant of this leakage path will be sufficient to dissipate the effects of expected errors in transmission at the decoder but not sufficient to mask the effects of the system being out of frame.

If the integrator voltage exceeds the limits set for a time longer than is expected due to errors in transmission, this indicates that the system is out of frame and an out-of-frame pulse is generated. This pulse then causes the framing to shift one position and restore the integrator voltage to the mean value of its ac excursions. This process is repeated as often as the integrator voltages exceed the limits set.

Since no other provision will be made for framing the incoming digital stream, except by correcting on recognition of the integrator voltage exceeding certain limits, the efficiency of framing by this process is critical. In an attempt to obtain an indication of the effectiveness of framing by this process, two approaches were made. The time constant of the integrator leakage path has not been determined but, because of the low error rates expected in UNICOM, this factor should not have a significant effect on the analysis and was therefore not considered. The two approaches were:

(1) With no signal input and the system out of frame, the times required to exceed the maximum allowable integrator voltage were calculated.

(2) Assuming a number of representative signals as inputs and the system to be out of frame, the times required to exceed the maximum allowable integrator voltage were considered.

ANALYSIS OF TIMES REQUIRED FOR SYSTEM TO EXCEED MAXIMUM ALLOWABLE VOLTAGE LIMITS

No Signal Applied to Inputs

A typical conversation can be described in terms of periods during which energy is emitted from the lips of each talker (called talkspurts), pauses within talkspurts, and periods after the termination of a talker's speech, during which the listener prepares to reply. From a Bell System study made of telephone conversations,[2] the following average intervals have been reported:

Average length of talkspurts: 4.14 seconds
Average length of pauses within talkspurts: 0.730 second
Average length of pauses between talkspurts: 0.410 second

[2]A. C. Norwine and O. J. Murphy, "Characteristic Time Intervals in Telephone Conversation," Bell System Technical Journal, April 1938, pp. 281-291.

In addition, the aggregate of all pauses within talkspurts amounts to about 17 percent of the total talkspurt time.

It can readily be seen from these figures that a considerable portion of normal conversation is composed of quiet intervals. Therefore, the decoder should be capable of rapid synchronization during these intervals. The successive quantized values during these periods will, in general, oscillate between +1 and -1. Figure 4A-1A shows the digital output of the encoder during quiet intervals based upon the code originally proposed (see Table 4A-1).[3] The possible framing positions given this digital stream are also shown, depending upon the number of positions the system is out of synchronism.

Table 4A-1

ORIGINAL CODING SCHEME FOR LOG-DIFFERENTIAL PCM CODER

Quantized Value	Code
+128	0 1 1 1
+64	0 1 1 0
+32	0 1 0 1
+16	0 1 0 0
+8	0 0 1 1
+4	0 0 1 0
+2	0 0 0 1
+1	0 0 0 0
-1	1 0 0 0
-2	1 0 0 1
-4	1 0 1 0
-8	1 0 1 1
-16	1 1 0 0
-32	1 1 0 1
-64	1 1 1 0
-128	1 1 1 1

[3]The coding scheme shown in Table 4A-1 was a natural outgrowth of an encoder whose principles were outlined in Section 4 of System Engineering Plan for the UNICOM Preliminary Engineering Plan.

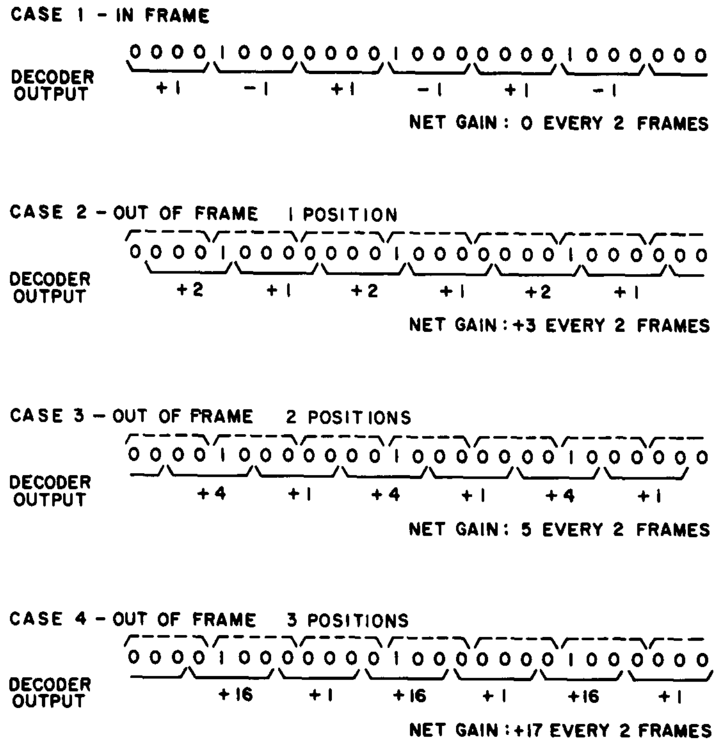


Figure 4A-1A. Log Differential PCM Coder Output with No Signal or Constant Amplitude Signal Applied (Based on Code Shown in Table 4A-1)

If the same assumptions used in the previous example are applied, the number of frames and times required for the integrator to exceed the maximum allowable voltage under each of the possible framing positions are shown below.

Out of Synchronism	Time Required to Overload Integrator: Frames	Milliseconds
1 position	300	31.25
2 positions	180	18.75
3 positions	54	5.63

In order to reduce the times required for the system to recognize out of synchronism during quiet intervals, the possibility of obtaining a more efficient code arrangement was investigated.

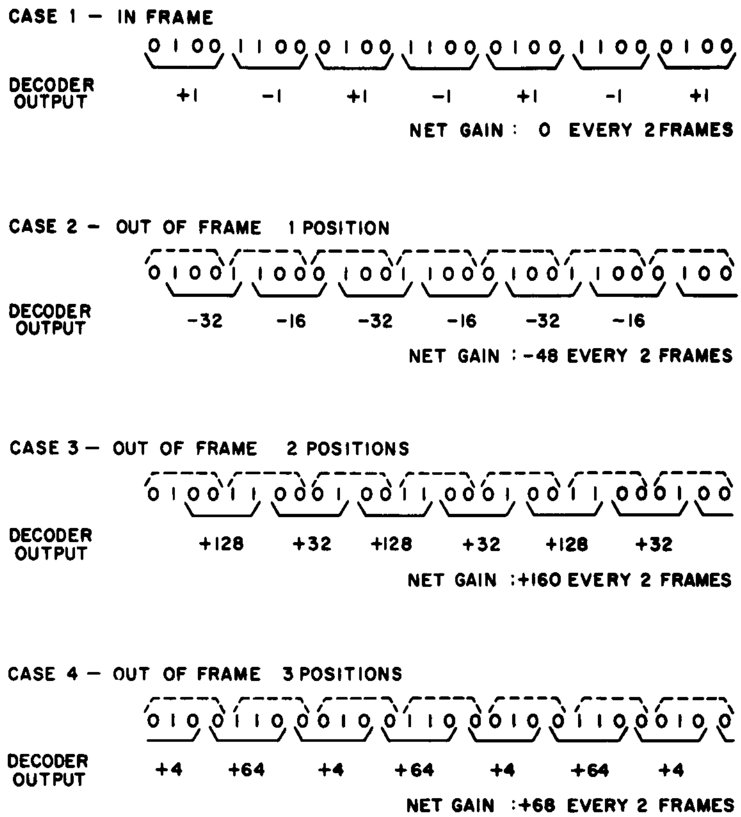


Figure 4A-1B. Log Differential PCM Coder Output with No Signal or Constant Amplitude Signal Applied (Based on Code Shown in Table 4A-2)

The code arrangement shown in Table 4A-2 is proposed as a means of achieving this end. This code can be obtained by an interchange of leads in the logic read-out of the proposed coder and does not require additional equipment or modifications.

Figure 4A-1B shows the digitized output from the encoder during quiet intervals based upon the code proposed in Table 4A-2. Depending upon the number of positions the system is out of synchronism, the possible framing positions given this digital stream are also shown.

Assuming zero initial voltage on the integrator and a 9600-frame-per-second sampling rate, the number of frames and times required for the integrator to exceed the maximum allowable voltage under each of the possible interpretations are shown below. The maximum allowable integrator voltage was 3.5 times the largest size step in the code. The voltage on the integrator is a monitonically increasing

Table 4A-2

PROPOSED CODING SCHEME
FOR LOG-DIFFERENTIAL
PCM CODER

Quantized Value	Code
+128	0 0 1 1
+64	0 0 1 0
+32	0 0 0 1
+16	0 0 0 0
+8	0 1 1 1
+4	0 1 1 0
+2	0 1 0 1
+1	0 1 0 0
-1	1 1 0 0
-2	1 1 0 1
-4	1 1 1 0
-8	1 1 1 1
-16	1 0 0 0
-32	1 0 0 1
-64	1 0 1 0
-128	1 0 1 1

function during these times. Note that three corrections would be required to reframe the system if it were out of synchronism by the maximum number of positions.

Out of Synchronism	Time Required to Overload Integrator	
	Frames	Milliseconds
1 position	20	2.08
2 positions	6	0.625
3 positions	14	1.46

It can be seen from the above that the proposed code is substantially more efficient than the original code. Even including the effect of the integrator leakage path, there should be more than sufficient time during pauses in conversations for the allowable integrator voltage limits to be exceeded and reframing to take place if the system were out of synchronism. With an average length of pause between talkspurts of over 400 ms, the system should be able to resynchronize even if it were out of frame by the maximum number of positions.

Representative Voice Inputs

The complex nature of the voice wave does not permit an exact analysis of the coder operation to be readily made. However, a signal composed of an 800-cps sine wave, exponentially damped and repetitive at a rate of 125 cps, is considered a useful model to represent a typical large amplitude voice wave.

For the analysis made, the damping exponential was chosen to have a decrement of 125, and the amplitudes of the sine wave were varied from 0.25 to 3.5 times the maximum step size. The signals were sampled at a 9600-cps rate and coded, using the code shown in Table 4A-1 as well as the code shown in Table 4A-2. The digital stream thus obtained was then decoded using various word framings, and the outputs were summed in a manner similar to that of the system decoder. The number of frames required for the unsynchronized outputs to exceed the maximum allowable integrator voltage was calculated for the various signals.

Based on the limited number of signals analyzed, it was observed that for most amplitudes of the sine wave the maximum allowable integrator voltage was exceeded within one decay interval. For some other amplitudes, several decay intervals were required to exceed the integrator limits. However, this appeared to be amplitude sensitive and a ±1-db variation in signal amplitude from these special values usually reduced the times required to exceed the integrator limits. This conclusion is based on a limited number of sample signals because of the amount of calculations required. There did not seem to be any apparent advantage in using one code scheme over another. For the larger amplitude signals, the code shown in Table 4A-1 appeared to be more efficient in detecting out of synchronism, while for smaller amplitude signals the code proposed in Table 4A-2 appeared to be more efficient for detecting out of synchronism. From these observations, there would seem to be a high probability of reframing the system, even during the presence of large amplitude signals.

CONCLUSIONS

Because of the nature of conversations, the code chosen for the four-digit log-differential PCM coder should enable the system to resynchronize rapidly during quiet intervals. The code shown in Table 4A-2 is proposed as an efficient code for this purpose. This code arrangement can be implemented with a minimum modification of the coder design originally proposed.

To assure initial synchronization of each connection, a quiet interval of approximately 75 milliseconds imposed at the start of each conversation should be sufficient. Once in synchronism, the system should maintain synchronous operation for the duration of the connection. If for any reason synchronism should be lost during the connection, the code would cause the system to resynchronize during the average duration of a pause between talkspurts, and probable even during talkspurts.

Appendix 4B

PRESENT ENGINEERING PLAN FOR OPERATING FACSIMILE IN THE UNICOM NETWORK

J. J. Horzepa

As part of the plan to eliminate 9.6 kbps as a data rate for digital stations in the UNICOM network, the possible operation of facsimile at the standard data rates of 2.4 and 38.4 kbps was investigated. The plan presented here was arrived at after a consideration of several possible schemes.

This appendix is divided into three parts. In the first part, a system plan will be presented for compatible facsimile transmission between analog stations and digital stations operating at 2.4- and 38.4-kbps data rates. The second part will present the plan for demonstrating the feasibility in the Test Model. The concluding part will discuss other studies and possibilities for transmitting facsimile.

SYSTEM PLAN FOR TRANSMITTING FACSIMILE

Basically, there will be two types of facsimile transmitted in the UNICOM network: (1) facsimile requiring multigray levels of definition, such as reconnaissance photographs and (2) facsimile requiring only black and white definition, such as weather maps. Each of these types may be used at digital stations operating at data rates of 2.4 and 38.4 kbps, as well as at analog stations. In order to provide a flexible system, full interconnections for transmitting facsimile between similar types of facsimile equipment will be provided, regardless of the stations involved.

The following requirements must be satisfied to permit compatible transmissions of facsimile between any two stations in the UNICOM network using similar types of facsimile equipments:

(1) The facsimile equipments will be capable of being started and phased automatically on signal.[1]

(2) The facsimile equipments at the originating and terminating stations will have the same index of cooperation.

[1] See Possible Semiautomatic Operation in this appendix for a discussion of possible operation of facsimile in the UNICOM network using equipment requiring manual starting and phasing.

(3) Both originating and terminating digital stations will use the same sample coding scheme for digitizing the facsimile baseband signal.

(4) The scan rates of the facsimile equipments will be a function of the frequency of the facsimile baseband signal, the sample coding scheme employed, and the data capacity of the station line. The scan rates used by the same type of facsimile equipments at digital stations will be related by the data rates of the stations.

(5) The frequency and duration of the supervision signals used to start, phase, and stop the facsimile equipments will be related by the data rates of the stations.

(6) Analog-digital converters employing compatible coding schemes for the various types of facsimile equipments will be provided for transmissions between the analog and digital networks.

Method of Operation

The following method will be used to provide full interconnections for transmission of facsimile between similar types of facsimile equipments:

(1) Transmission of facsimile between UNICOM stations in the same network and operating at the same data rates will be direct or indirect.

(2) Transmission of facsimile between digital stations operating at dissimilar data rates will be indirect. The store and forward (S/F) unit in the switching center will be used to store the digital facsimile information from the originating station. After a connection has been set up to the terminating station, this information will be retransmitted from the S/F unit at the terminating station data rate. After speed buffering, the scan rate, supervision signals, and data rate will be compatible with the terminating facsimile equipment.

(3) Transmission of facsimile between the analog and digital networks will be indirect. Facsimile messages from an analog station intended for a digital station will be received at the switching center, demodulated to extract the facsimile baseband signal, sampled and encoded to digital form, and stored in the S/F unit. After a connection has been set up to the digital terminating station, the digitized information will be retransmitted from the S/F unit at the terminating station data rate. As a result of this process, the message will be in compatible form for the terminating facsimile equipment. The reverse process will be followed on calls from the digital network intended for a station in the analog network.

Advantages

The above plan for handling facsimile transmissions offers the following advantages:

(1) Facsimile information may be transmitted between any two stations in the UNICOM network employing the same type of facsimile equipment.

(2) Full efficient use is made of the data handling capacity of each station in the network during facsimile transmission.

(3) Common equipment is used in the S/F unit of the switching center for transmissions between stations operating at incompatible data rates.

TEST MODEL PLAN

The Test Model will be used to demonstrate the feasibility of transmitting facsimile between digital stations by the plan outlined above. At the present time, there is no requirement to demonstrate the feasibility of transmitting facsimile between the analog and digital networks and this feature will not be implemented in the Test Model. However, for completeness of description and the possible desirability of implementing this feature, the Test Model plan will include the possibility of both digital as well as digital-to-analog facsimile transmissions.

Equipment Required

The AN/GXC-4 facsimile equipment is the only type of equipment investigated that is capable of automatic operation and could be readily modified for use in the Test Model. It will be possible to demonstrate the feasibility of the system plan using two AN/GXC-4 send and receive sets.

The AN/GXC-4 facsimile equipment manufactured by the Westrex Corporation will be modified by special UNICOM requirements for use in the Test Model. The basic characteristics of this equipment are:

Copy size: 3-1/4 by 4-1/4 inches

Intelligence area: 2-7/8 by 3-13/16 inches

Index of cooperation (diametral): 264

Line advance: 255 lines per inch

Useful scanning: 88 percent of scan cycle

The following modifications will be made to the basic unit for this proposal:

(1) Scan Rates: The equipment will be capable of operating at scanning rates of 30, 120, and 480 lines per minute.

(2) Supervision: Supervision means the method of passing STOP, START, and PHASE information to the receiver. Supervision signals will be a function of the scanning rate, as shown in Table 4B-1.

(3) Blanking Circuit: The level of the blanked signal will be the same as the level used for black picture. In addition, the output of the blanking contacts will be brought out for connection to the pulse code modulation (PCM) encoding unit.

(4) Transmitter Output: The facsimile dc baseband will be available to the PCM encoder.

(5) Receiver Input: The receiver will be capable of operating with the facsimile dc baseband as an input signal.

Table 4B-1

SUPERVISION FOR FACSIMILE

Scan Rate (lines per minute)	Stop: Frequency (cycles per second)	Stop: Time (seconds)	Start: Frequency (cycles per second)	Start: Time (seconds)	Phase Time (seconds)
30	112.5	16	75	16	28
120*	450	4	300	4	7
480	1800	1	1200	1	1.75

*This is a standard scanning rate and method of supervision of the unmodified AN/GXC-4 for analog use.

Method of Operation

In the plan described here, two types of digital stations will be required, one for each of the standard data rates. Since the AN/GXC-4 machine is usually used for facsimile requiring multigray levels, a six-digit PCM code will be employed to digitize the facsimile baseband signal. In order to keep within the data rate capacity of the station lines, stations on 2.55-kbps lines (2.4-kbps data rate) will operate this equipment at a scan rate of 30 lines per minute, while stations on 40.8-kbps lines (38.4-kbps data rate) will operate the equipment at a scan rate of 480 lines per minute. Stations on the analog network will use equipment operating at a scan rate of 120 lines per minute with corresponding supervision. The dc baseband facsimile signal will amplitude-modulate a 2400-cps carrier which will be transmitted.

Direct Interconnections. Direct transmission of facsimile will be possible between any two stations in the same network. Connections between stations which operate at the same scan rate and data rate will be handled in the same manner as other data transmissions.

Indirect Digital Interconnections. Stations operating at unlike data rates will use S/F means to send traffic between them. The S/F unit in the switching center will provide the speed buffering required to make the bit rates compatible. After speed buffering, the supervision signals, scan rates, and information bits will be of the proper frequency and timing for the terminating stations. As a result of this process, the station lines and equipment will be used at their full capacity.

Example: In Figure 4B-1, Station A, operating at a 2.4-kbps data rate, has a facsimile message intended for Station B, operating at a 38.4-kbps data rate. Station A, after establishing a connection to the S/F unit in the switching center, will transmit the information at a 30-line-per-minute scanning rate and 2.4-kbps data rate. At the end of the message, a connection will be made to Station B, and the information will be retransmitted at a 38.4-kbps data rate. As a result of the 16:1 increase in bit rate, the supervisory frequencies will be increased by a factor of 16; the time duration of the supervisory signals will be reduced by a factor of 16; and in addition the scanning rate will be increased by a factor of 16. Thus the message is received in required format at the terminating station.

Digital-Analog Interconnections. If the possibility of facsimile transmission between the digital and analog networks were to be implemented, the service would be indirect. A PCM coder-decoder and an analog facsimile mod-demod unit would be provided between the space-division matrix (SDM) and time-division matrix (TDM) for these connections. Facsimile messages from an analog station intended for a digital station would be received at the switching center, demodulated and reduced to the baseband signal, coded by a six-digit PCM coder to a 9.6-kbps data rate, and stored in the S/F unit in the switching center. After a connection had been established to the digital station, the message thus digitized would be retransmitted at the digital station data rate. Facsimile messages in the reverse direction would be received and stored in the S/F unit in the switching center in digital form. After a connection had been established to the analog station, the digital information would be speed buffered to the 9.6-kbps data rate, decoded by the six-digit PCM decoder, and restored to baseband. The resulting facsimile baseband signal would then be used to amplitude-modulate the 2.4-kcps carrier which would be transmitted to the analog station. By this process, the messages would be received at the terminating station with proper supervision signals and scan rate. Figure 4B-2 shows an example of such a connection.

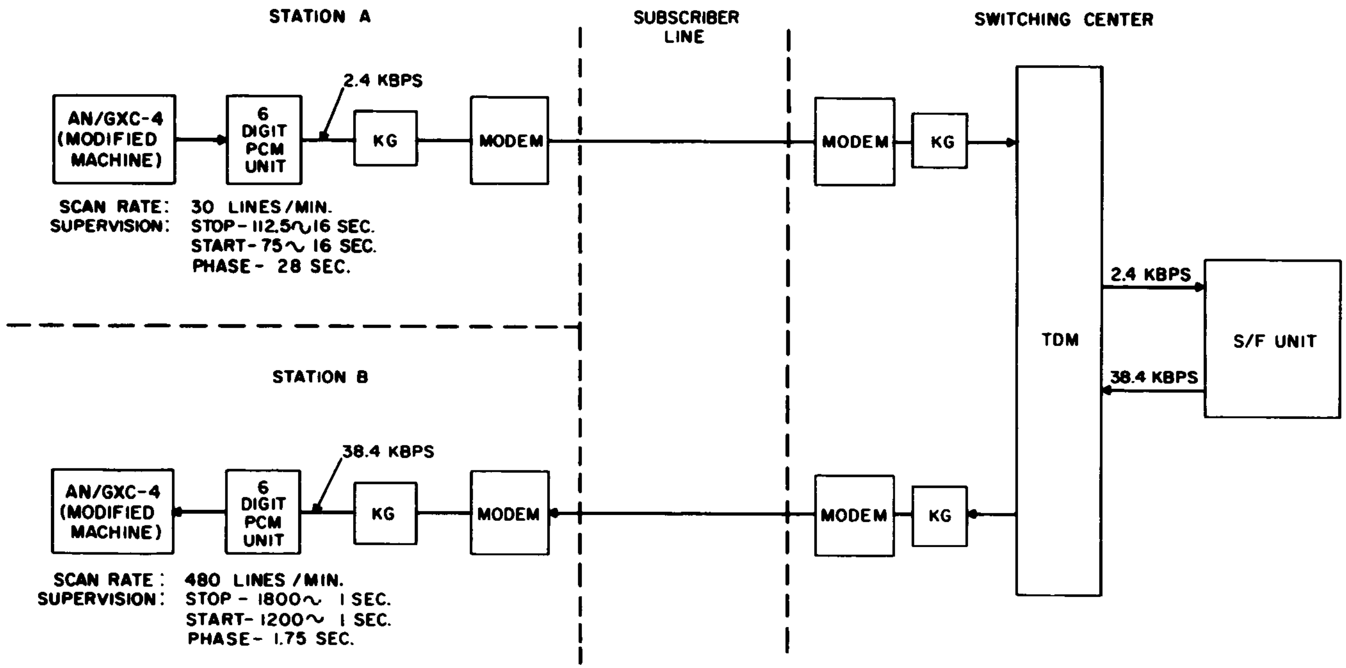


Figure 4B-1. Facsimile Transmission-Digital Stations Operating at Incompatible Data Rates

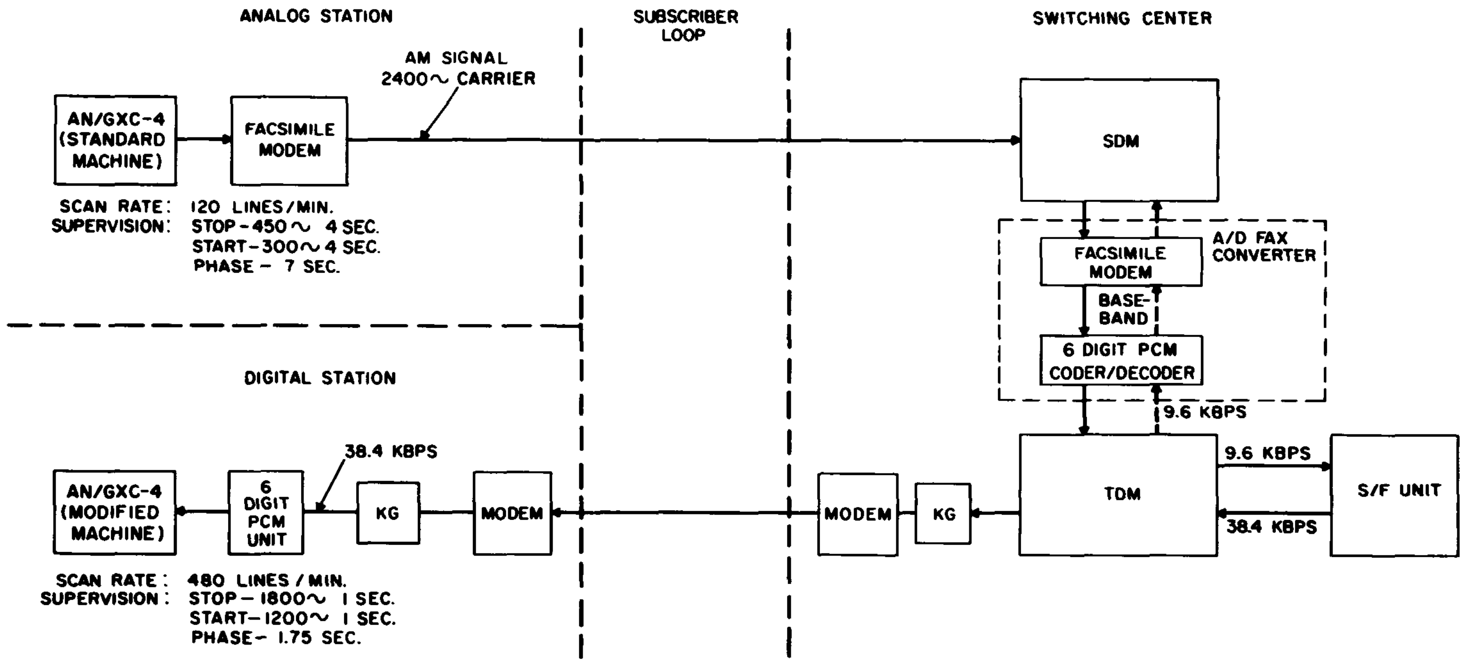


Figure 4B-2. Facsimile Transmission-Analog-Digital Interconnection

Possible Use of Differential PCM for Coding Facsimile Baseband Signal

In addition to demonstrating the feasibility of transmitting facsimile between digital stations by the System Engineering Plan, the equipment provided for the Test Model will be used to investigate the feasibility of using four-digit differential PCM for coding the facsimile baseband signal. This type of coding offers the possibility of a self-synchronizing transmission code and would allow a 50-percent increase in the allowable scan rates indicated. It is expected that the four-digit log differential PCM encoder being developed for digitizing voice over 40.8-kbps lines can be modified for use in encoding the facsimile baseband signals at digital facsimile stations.

OTHER STUDIES AND ALTERNATIVES

In addition to the demonstrations and tests to be made in the Test Model, the following possibilities will be investigated in pre-Test Model tests.

Black and White Facsimile

It is anticipated that there will be significant demand in the UNICOM network for the transmission of facsimile information requiring only black and white definition. Because of the nature of this type of facsimile, it is expected that a one-digit or at most a two-digit sample code could be used to encode the facsimile baseband signal. Coding the signal in this manner would permit an increase in allowable scan rates and a corresponding reduction in facsimile transmission times at digital stations of 3 to 1 using a two-digit sample code and 6 to 1 with a one-digit sample code. The use of a one-digit sample code would allow standard facsimile equipments whose baseband signal frequency is 1200 cycles or less to be used over 2.55-kbps lines. In general, most standard facsimile equipments have a scan rate with a baseband signal frequency which falls within this range. The question of which sample coding scheme is adequate will be determined during pre-Test Model testing. In addition, pre-Test Model tests will be used to investigate the feasibility of implementing the Test Model to demonstrate the transmission of this type of facsimile.

Alternate Operation at Digital Stations

It has been proposed that facsimile connections between digital stations operating the same type of facsimile equipments at different data rates be by indirect means. However, if it becomes a requirement that provision be made for direct interconnections of such stations, the facsimile information would be transmitted at the scan rate and data rate of the low-speed station. This would be accomplished at the high-speed station by providing means to shift the facsimile machine to low scan rate operation and making provision to send and receive at a 2.4-kbps information rate over the 40.8-kbps lines. These shifts could be actuated automatically by supervision from the switching center upon recognition of the type of connection.

Although this method of operation is possible, it is not recommended because of the inefficient use made of the high-speed line and station equipment by transmitting facsimile at a low scan rate to a normally high scan rate station, as well as increasing the complexity of the station logic. Also, preliminary studies indicate that this direct method of operation will not result in substantial time savings in delivery of the facsimile message over the indirect method.

Possible Semiautomatic Operation

The system plan was based on the premise that the facsimile equipments used in UNICOM will be capable of being started, phased, and stopped automatically on signal. However, most of the facsimile equipments presently in use require attendants at each end of the circuit to be in voice communication in order to start and phase the equipments before facsimile information is transmitted. Until sufficient automatic facsimile equipments are developed to satisfy the various needs of the services (i.e., meteorological, field, and general utility equipments), it may be desirable in some cases to transmit direct facsimile by the above method.

This type of operation could be provided in UNICOM by establishing a voice-data connection between stations in the same network operating similar type equipments at compatible scan rates. This would allow the use of standard equipments at digital stations, provided the baseband signal frequency could be accommodated by the required sampling rates. The facsimile equipments and, if necessary, the PCM equipments would be started and phased by attendants at each end before transmission of the facsimile information.

Appendix 6A

ORGANIZATION OF THE SWITCHING CENTER CENTRAL PROCESSOR PROGRAM

K. A. Heller

SWITCHING CENTER CENTRAL PROCESSOR PROGRAM

The organization of the central processor (CP) program is shown in block diagram form on Figure 6A-1. The CP program is divided into three major parts: the main operational program, the periodic interrupt program, and the maintenance interrupt and restore program.

All the logic decisions concerned with the operation and control of the switching center and with maintenance are performed within the main operational program. Hence, this is the largest of the three programs that make up the CP program. Its organization is discussed in this appendix (Organization of the Main Operational Program).

The periodic interrupt program controls the transfer of most of the signals and data between the call store and the external equipments. It also takes care of all operations which must be performed at a fixed periodic rate, such as the clock advance operation. Its organization is discussed in Organization of the Periodic Interrupt Program.

The maintenance interrupt and restore program operates only when an equipment error is detected within the CP. Its first function, the maintenance interrupt function, is to analyze the error and take appropriate corrective action. In so doing it makes use of the maintenance programs which are part of the main operational program. Its second function, the restore function, is to determine whether or not the operation of the periodic interrupt program was disturbed by the operation of the maintenance interrupt and restore program and, if so, to take the necessary corrective action. The organization of the maintenance interrupt and restore program is in the very early stages of development; it is not covered in this appendix.

Program Intercommunication

Intercommunication of information between programs is accomplished by means of tables stored in the call store (temporary memory). Each program obtains

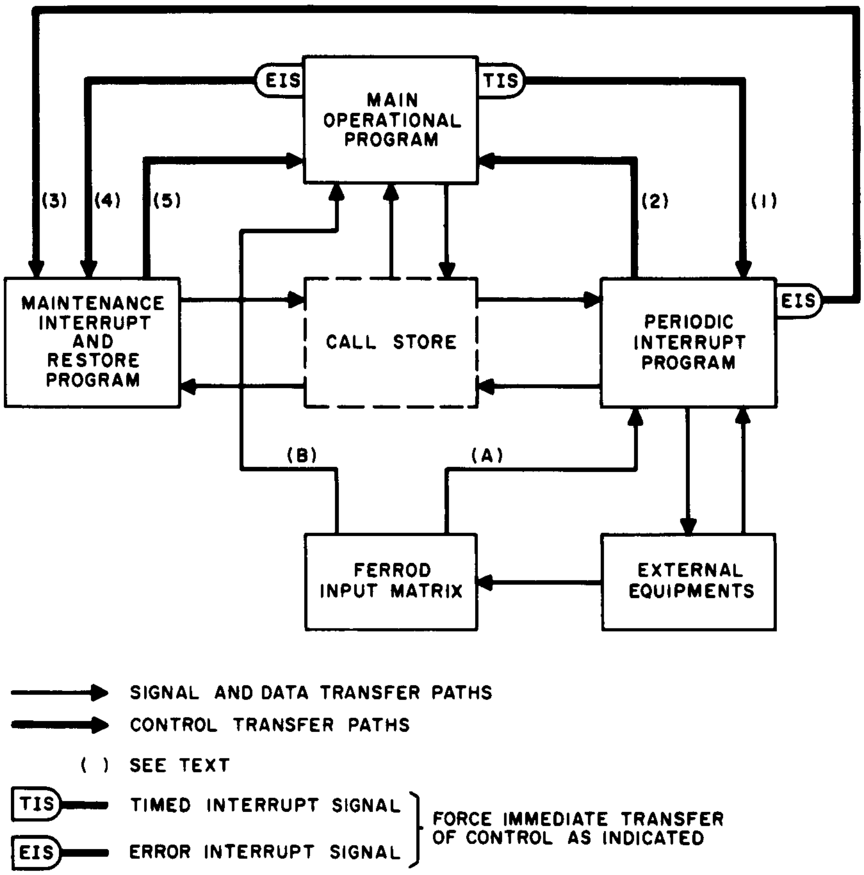


Figure 6A-1. Organization of Switching Center Central Processor Program

the information it requires from one or more of the tables, processes the information, and stores the results in the proper places in the tables. The paths along which these signals and data are transferred are indicated by the light lines in Figure 6A-1. The light lines also indicate the paths along which signals are transferred between the call store and the external equipments, including the ferrod input matrix. Some of the signals from the ferrod input matrix are transferred to the call store by the periodic interrupt program (path A). The rest of the signals from the ferrod input matrix are transferred to the call store directly under the control of the main operational program (path B).

Transfer of Control

Transfer of control between the three programs that comprise the CP program is restricted to the paths indicated by the heavy lines in Figure 6A-1.

Normally, the main operational program is in control. It is a cyclical type program that performs all functions necessary for the operation of the switching center at least once every 250 ms. Periodically, every 3-1/3 ms, the periodic interrupt program must operate. To effect the necessary transfer of control, a timed interrupt signal (TIS) is generated by the CP equipment every 3-1/3 ms. In response to a TIS, the main operational program is interrupted, the address of the next instruction to be executed by the main operational program is stored, and control is transferred to the periodic interrupt program (transfer path 1 in Figure 6A-1). The operate time of the periodic interrupt program is considerably less than 3-1/3 ms. When its operation is complete, control is transferred back to the main operational program (transfer path 2 in Figure 6A-1) and the main operational program continues with the instruction whose address was stored when it was interrupted by the TIS. In the absence of errors, the transfer of control between the main operational program and the periodic interrupt program occurs every 3-1/3 ms as described, and this transfer constitutes the normal exchange of control within the CP program.

Special error detecting equipments are located at various points throughout the CP. When a trouble is detected, the appropriate error detecting equipment generates an error interrupt signal (EIS). An EIS can be generated at any time. When one occurs, the address of the next instruction to be executed and the contents of the computer operational registers are stored. The address of the next instruction to be executed in this case is for an instruction in either the main operational program or the periodic interrupt program, dependent upon which one had control at the time the EIS occurred. Control is then transferred immediately to the maintenance interrupt program (transfer path 3 or 4 in Figure 6A-1). As already stated, the maintenance interrupt and restore program analyzes the trouble and takes whatever action is necessary to correct it. Upon completion of the maintenance interrupt function, the restore function is performed.

The necessity for a restore function may be developed from the following reasoning. The main operational program is concerned with logical decisions only; consequently, it can be interrupted at any time for any length of time without disturbing the logical function being performed other than to cause a delay in its completion. The periodic interrupt program, however, is concerned with the clock functions and signal and data transfer operations which must be performed periodically, or at a rate approximately synchronous with real time. Consequently, any interruption or delay in the operation of the periodic interrupt program can disturb these functions which must be performed periodically. As a result, the restore program must operate after each maintenance interrupt operation to determine whether or not the functions of the periodic interrupt program were disturbed. If they were, the restore program takes appropriate action to compensate for the disturbance. Control is then transferred back to the main operational program (transfer

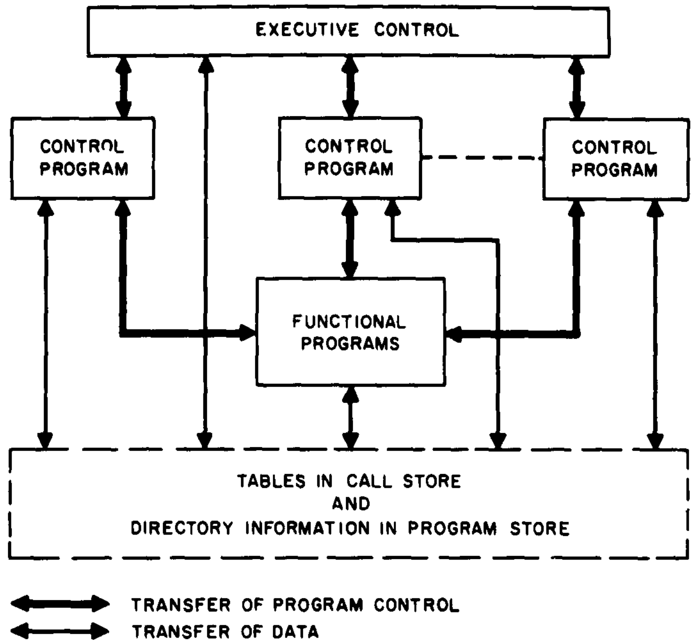


Figure 6A-2. Organization of Main Operational Program

path 5 in Figure 6A-1). The instruction which is next executed is not necessarily the instruction whose address was stored at the time the EIS occurred; it may be this instruction or an instruction at an address decided upon by the restore program. If a TIS is present at the time control is returned to main operational program, it will be recognized, of course.

ORGANIZATION OF THE MAIN OPERATIONAL PROGRAM

The general organization of the main operational program is shown in block diagram form in Figure 6A-2. The solid line boxes indicate programs. The dotted line box indicates tables or temporary storage areas in the call store and the directory in the program store. Transfer of control and transfer of signals are indicated by the heavy and light lines, respectively, as in Figure 6A-1.

Three kinds of programs make up the main operational program: an executive control program, several control programs, and several functional programs.

Executive Control Program

The executive control program controls the sequence of operation of the control programs. Executive control decides which control program is to operate next and transfers control to that program. Upon completion of its operation, the control program returns control back to executive control, etc.

The sequence in which the control programs are operated is not necessarily fixed. Under high-load conditions, certain of the control programs which are not directly concerned with traffic and call processing may be operated less frequently. The dynamic adjustment of the sequence is accomplished by means of sequence parameters within the executive control program and is automatic. In addition, certain of the control programs may have to operate more frequently at certain times than at others. To satisfy this requirement, a feedback mechanism is provided to allow these programs to notify executive control of the rate at which they must operate at any given time. In response, executive control automatically adjusts the sequence parameters accordingly.

It is important to distinguish that, within the main operational program, transfer of control among the various control programs is under control of the executive control program; whereas, transfer of control between the main operational program and the other two major CP programs is under control of equipment-generated interrupt signals as described in the section, Switching Center Central Processor Program.

Control and Functional Programs

Each control program is responsible for the performance of a specific sequence of events in the switching center. Each functional program is responsible for the performance of a specific function. In this context, the former is a more encompassing job or area of responsibility than the latter. As a result, a control program may call upon a functional program to perform a specific function. To do this, the control program transfers control to the appropriate functional program. The functional program performs the function and immediately transfers control back to the control program that called it in. The reason for not building the functional capability into the control program is that the functional capabilities are in general common to several control programs. Hence, programming efficiency is gained by allowing the control programs to make use of the common functional programs as required.

The following ground rules for transferring control between control and functional programs apply:

(1) A control program may transfer control to a functional program.

(2) A functional program always transfers control back to the control program that transferred control to it. Occasionally the functional program may transfer control to a second functional program which will transfer

control back to the first functional program, after which control is transferred back to the control program. In general, however, functional programs will be written as closed routines.

(3) A control program never transfers control to another control program. It always transfers control back to executive control.

Tables 6A-1 and 6A-2 are preliminary lists of the nonmaintenance control and functional programs that are currently envisioned for the main operational program. Perusal of these lists reveals what some of the operations and functions are.

Table 6A-1

PRELIMINARY LIST OF CONTROL PROGRAMS WITHIN THE MAIN OPERATIONAL PROGRAM

Executive Control
Signal Sort Control, Digital Signals
Signal Sort Control, Originating Register
Signal Sort Control, Incoming Register
Signal Sort Control, STARCOM Register
Scan Control, Analog Intra-Office Trunk
Scan Control, Tone Trunk
Scan Control, Analog Inter-Office Trunk
Scan Control, Analog-Digital Converter Trunk
Signal Processing Control, Digital Lines State 1
Signal Processing Control, Digital Lines State 2
Signal Processing Control, Digital Lines State 3
Signal Processing Control, Digital Lines State 4
Signal Processing Control, Digital Trunks State 1
Signal Processing Control, Digital Trunks State 2
Signal Processing Control, Digital Trunks State 3
Signal Processing Control, Digital Trunks State 4
Signal Processing Control, Analog Lines State 1
Signal Processing Control, Analog Lines State 2
Signal Processing Control, Analog Lines State 4
Signal Processing Control, Analog Trunks State 1
Signal Processing Control, Analog Trunks State 2
Signal Processing Control, Analog Trunks State 4
Signal Processing Control, STARCOM Lines State 1
Signal Processing Control, STARCOM Lines State 2
Signal Processing Control, STARCOM Lines State 4
Signal Processing Control, Traffic Attendants Console

Signal Processing Control, Supervisory Console
Signal Processing Control, Maintenance Console
Signal Processing Control, Status
Output Signal Control, Digital Signals
Output Signal Control, TDS
Output Signal Control, SDS
Output Signal Control, Console Group
Output Signal Control, Tape
Simulation Control
S/F Control
Time Out Control
Recording Control
Startover Control
Card Makeup
Directory Change Control
Automatic Restoral Control

Table 6A-2

PRELIMINARY LIST OF FUNCTIONAL PROGRAMS WITHIN THE MAIN OPERATIONAL PROGRAM

Conference Call Processing
Broadcast Call Processing
Path Hunt, SDS
Path Hunt, TDS
Output Message Makeup, SDS
Output Message Makeup, TDS
Output Message Makeup, Console Group
Output Message Makeup, Typewriter
Output Message Makeup, Tape
Output Message Makeup, Digital Signals
Output Message Makeup, Analog Signals
Multiaddress Overflow Processing
Route Selection, Direct
Route Selection, Indirect
Trunk Hunt, Direct
Trunk Hunt, Indirect
Call Verification, Originating Subscriber
Call Verification, Terminating Subscriber
Recording, Trouble Calls
Recording, Status Data

Table 6A-2 (continued)

Pre-emption, Trunks
Pre-emption, SDS Path
Pre-emption, TDS Path

Clarification of the distinction between the control and functional programs is aided by the following example: The Signal Processing Control, Analog Lines State 1 control program has the responsibility for processing service requests from analog subscribers. Each time control is transferred to this program, it reads into call store an image of the ferrods that contain the on-hook, off-hook data for analog subscribers lines. It compares this image with the image read the last time this control program operated to determine which analog subscribers are requesting service. Then this program takes each of the service requests in turn (one at a time) and processes it, using whatever functional programs are required. The processing consists of finding an available call slot (see Program Intercommunication in this appendix), finding an available originating register, searching for a path through the space-division switch (SDS) that connects the subscriber's line terminal with the terminal of the originating register, ordering the connection of the originating register, and finally doing all the necessary bookkeeping operations pertinent to the actions it took. After all service requests have been processed in this way, the control program returns control to executive control.

While performing this operation, the Signal Processing Control, Analog Lines State 1 control program calls upon the Path Hunt, SDS functional program each time it has to perform an SDS path hunt. It also calls upon the Output Message Makeup, SDS functional program each time it has to order that a connection be established between a pair of terminals in the SDS.

This example serves to illustrate the difference in the degree of responsibility between control and functional programs and hence the method for distinguishing between the two.

Maintenance programs, other than the maintenance interrupt and restore programs previously mentioned, are also part of the main operational program. One of these programs, the maintenance control program, controls all maintenance operations. This program is entered in three ways: from the executive control program periodically, from the executive control program when one of the other control programs detects an error, or from the maintenance interrupt program. The periodic entry permits the maintenance programs to perform prognostic tests in an attempt to find troubles before they affect service. The other two entries are for the purpose of trouble diagnosis and correction.

Subprograms and Subroutines

Subprograms and subroutines have no specific operational or functional capabilities as to control and functional programs respectively. They are distinguished as follows.

Subprograms are the result of dividing a large program package, such as a control or functional program, into two or more parts.

Subroutines are the result of recognizing that an identical set of instructions may occur several times within a large program system, such as within a control or functional program or among several control and functional programs. Such a set of instructions is included only once in the program store as a subroutine to be operated at the appropriate times for programs that would normally contain this set of instructions.

Program Intercommunication

Intercommunication of signals and data among the executive control, control, and functional programs within the main operational program is via tables and queues maintained by the programs in the call store. This mechanism is the same as described previously for program intercommunication among the three major programs that make up the CP program. Some of the more important tables are the call-slot table, the facilities-available table, and the sort table.

The call-slot table is made up of many call slots. In order to establish and maintain a call in the switching center, a call slot is required. Hence, the number of call slots must equal the maximum number of simultaneous calls that must be maintained in the switching center at any given time. When a service request is processed, one of the first things to be done is to assign an available call slot to the subscriber or trunk requesting service. All the information pertinent to the call is stored in the call slot and, as the call progresses, the various control and functional programs that get involved in the processing refer to the assigned call slot for information and modify the contents of the call slot in accordance with actions taken.

The facilities-available table is the region of the call store where the control and functional programs maintain a bookkeeping-type record of the availability status of all facilities at the switching center including the call slots. The availability status stored for each facility includes such items as busy or not busy, temporarily out of service because of routine maintenance, out of service because of failure, and in service but with trouble indicators set for this facility. The control and functional programs store status information in the facilities-available table as the status information changes and make use of this information as required.

The sort table is a region of call store where the control and functional programs maintain a bookkeeping-type record of the tables to which input signals from various external equipments are to be routed when they are received. The sort-control programs use the information stored in the sort table when sorting the input signals and route the signals to the appropriate tables for subsequent processing. It is important to recognize that the input signal sorting or routing data in the sort tables changes as the state of the source of the signal changes. For example, a subscriber's line circuit is in state 1 when it is idle. Signals in this case are routed to queues for possible service request processing. A subscriber's line busy with a call is in state 2. In this case, signals are routed to tables for possible end of message, call cancellation, or call termination processing. In addition, signals are routed to different queues depending on whether they are received from a subscriber's line or a trunk. This is because signals received from trunks are processed more frequently than signals received from lines, to insure that inter-switching-center calls involving one or more tandem switching-center connections are processed within the required time limits.

Directory

A directory is permanently stored in the program store. It contains all the fixed data required by the control and functional programs, such as the relationship between telephone numbers, and equipment terminal numbers; and maximum precedence and security privileges allowed each subscriber. Changes to the directory are stored in a special table of call store until they can be incorporated in the permanently stored directory. The various programs refer to the change directory each time a directory look-up is made to insure that the most recent directory information is used.

ORGANIZATION OF THE PERIODIC INTERRUPT PROGRAM

The organization of the periodic interrupt program is shown in block diagram form in Figure 6A-3. It contains one sequence control program, several transfer programs, and one periodic bookkeeping program. The sequence control program is a control type program and the rest are functional programs.

The sequence control program controls the sequence in which the functional programs operate each time the periodic interrupt program operates. There is one transfer program for each kind of input and output signal that must be transferred at a periodic rate between the external equipments and the call store. The periodic bookkeeping program is concerned with those functions that must be performed periodically such as advancing the computer clock.

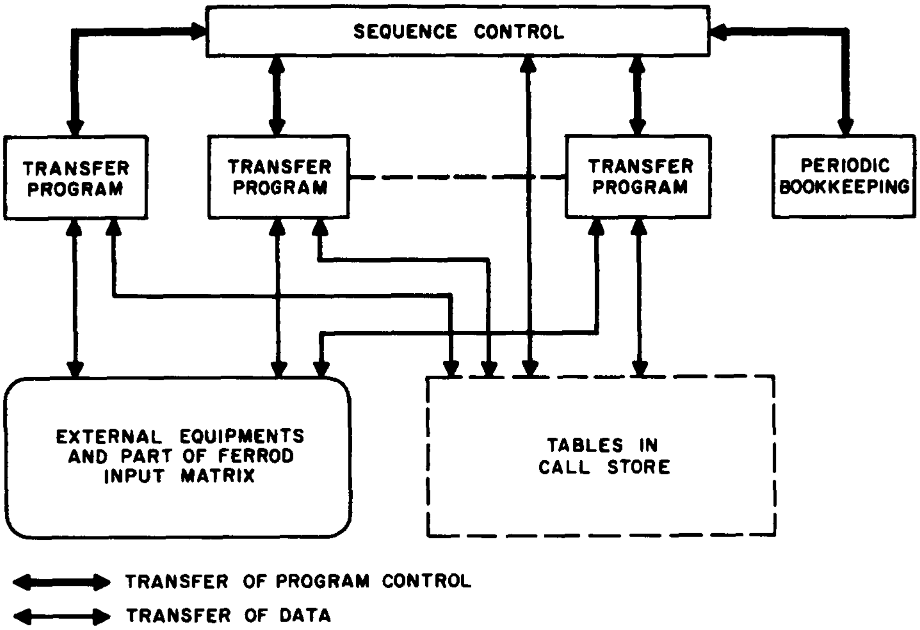


Figure 6A-3. Organization of Periodic Interrupt Program

An important characteristic of the periodic interrupt program is the following: The periodic interrupt program is operated once every 3-1/3 ms. It is not necessary, however, that all the functional transfer programs operate every 3-1/3 ms. Some only need to operate every third time the program operates, others every eighth time, etc. Those that must operate every third time are not all operated in the same operate cycle, but rather are staggered among three cycles to distribute the load and help minimize the operate time per operate cycle. The same is true for the functional programs that must operate less frequently. The achievement of this operation is the responsibility of the sequence control program.

OPERATIONAL CHARACTERISTICS OF MAIN OPERATIONAL PROGRAM

The operational characteristics of the main operational program and its relationship to the periodic interrupt program are best described with the aid of Figure 6A-4. Figure 6A-4 is for illustrative purposes only and is not intended to be exhaustive in all details.

The external equipments which are the source of input signals to the CP programs are shown at the extreme left of Figure 6A-4. Output signals from the CP program are delivered to the external equipments shown at the extreme right.

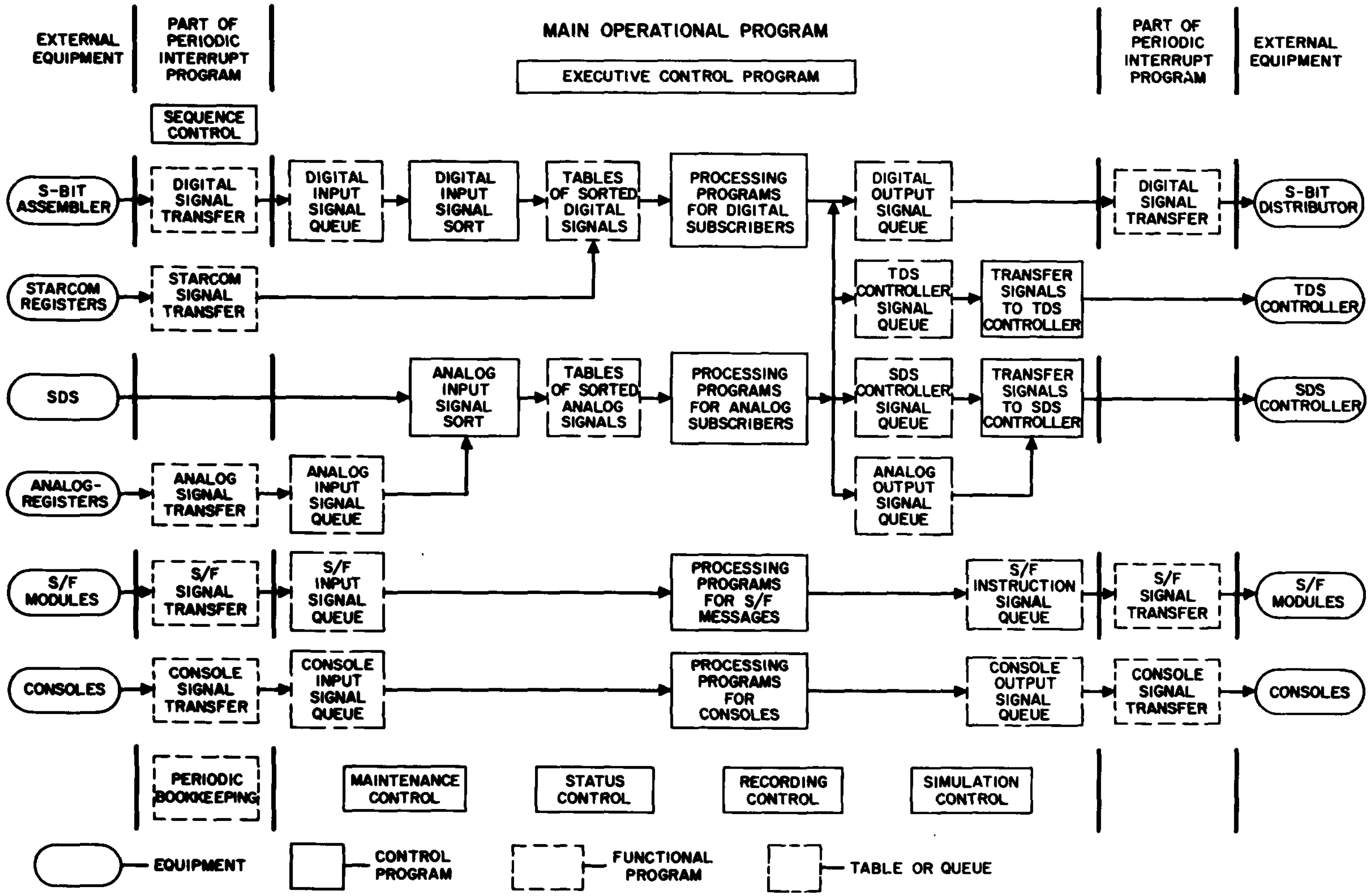


Figure 6A-4. Simplified Block Diagram of Main Operational and Periodic Interrupt Program

The solid line boxes indicate control programs, the dashed line boxes indicate functional programs, and the dot-dashed line boxes indicate tables or queues in the call store.

All the arrows in the figure indicate the transfer of signals through the program system. It is to be noted that signals and/or data are stored in tables or queues, not in programs. Hence an arrow extending from a table to a program indicates that the data in the table are used by the program; an arrow extending from a program to a table indicates that the program sets data in the table. Generally speaking, an input signal stimulus enters the program system on the left side of Figure 6A-4. It is stored in the first queue or table it encounters as it progresses toward the right. When the program immediately to the right of the queue or table in which it is stored operates, the stimulus is processed, probably converted in form and stored in the next queue or table to the right. This process of propagating the input stimulus continues until the input stimulus finally appears as one or more command or output signals from the CP to the external equipments on the right side of Figure 6A-4.

In addition to the propagation of stimuli from left to right, there is considerable communication between the control programs within the main operational programs via the call slot tables, the facilities-available table, etc. No attempt is made in Figure 6A-4 to show all these possible intercommunication paths.

Figure 6A-4 also does not show the transfer control paths between the various programs. It can be said, however, that within the main operational program, executive control sequences the control programs in a cyclical fashion such that the control programs on the left side of Figure 6A-4 operate early in the cycle and those on the right later in the cycle. This is consistent with the propagation of stimuli from left to right in the figure.

Every 3-1/3 ms, when the periodic interrupt program operates, those transfer programs that are shown on the left side of the figure and are scheduled to operate transfer any signals that may be present in the external equipment to the input queues, and those that are shown on the right side of the figure and are scheduled to operate transfer any signals that may be present in the output queues to the external equipments.

One important operational characteristic of each control program is that each is designed to operate in a single-thread fashion. When a control program is operated, it first looks to see if there are any input stimuli in the tables it uses. If not, it returns control to executive control. If there are input stimuli they may be one or many in number. But regardless of the number, the control program takes one stimulus from the table (a single stimulus may be a set of signals) and does all the processing related to that stimulus that is possible. It then picks up the next stimulus in the table and does the same. When all the stimuli in the table have been processed, the control program returns control to executive control.

It is to be noted that in the performance of an operation a control program may have to order a connection in the external equipment as indicated in the example presented in the last paragraph of Control and Functional Programs under Organization of the Main Operational Program in this appendix. The execution of a command by external equipment takes time and it is undesirable for the control program to wait for the command to be executed. Hence, the generation of a command or an output signal by a control program is considered the completion of the single-thread processing by the control program. This signal is stored in an output queue to await transfer to the equipment by another program when the equipment is ready to accept a new signal. In this way the control program can immediately proceed with processing the next input stimulus as soon as it has stored the last output signal it generated in the output queue.

SUMMARY

An attempt has been made in this appendix to provide preliminary information on the planned organization and operation of the switching center CP program system. The functional specification, when complete, will provide considerably more detail on the specific operation and capabilities of the various programs.

Appendix 6B

TRAFFIC ATTENDANT CONSOLE, DESIGN PROPOSAL

R. F. Cook

This appendix describes the proposed traffic attendant console which provides the facilities for handling calls requiring the assistance of an operator. Although some discussion of the circuit design approach is included, the primary intent is to describe how the various proposed controls and displays on this console are used by the operator in performing the many call handling functions.

The traffic attendant position consists of a cordless operating position, in which calls are presented to the operator by the central processor (CP), in an order determined by precedence and/or call filing time. The console is provided with a keyset which can set up all the possible preamble headings for originating both analog and digital calls. A teletypewriter (TTY) is provided at the attendant's position for the use of the operator, as well as other console operators and maintenance personnel. This facility is used to communicate with subscribers and other offices and is not intended as a device to send and receive information from the central control. A separate typewriter such as a Flexowriter will be provided at the attendant's position to print information from the central control about subscriber keying irregularities, calls not meeting speed of service requirements, heading validity checks, etc.

The control consoles require a relatively large quantity of data from the central control to control the various displays ar , operate control relays. A signal distributor which will be used by all the consoles has been proposed. Likewise, the consoles initiate control instructions which are carried out by the central control. The ferrod scanner is used to send these instructions from the control keys on the consoles into the central control. A block diagram of the attendant's position and the interconnection of this console with other switching center equipments is shown in Figure 6C-1.

OPERATOR TRUNKS

As was mentioned earlier, central control presents one call at a time to the operator in an order determined by precedence and call filing time. Because the

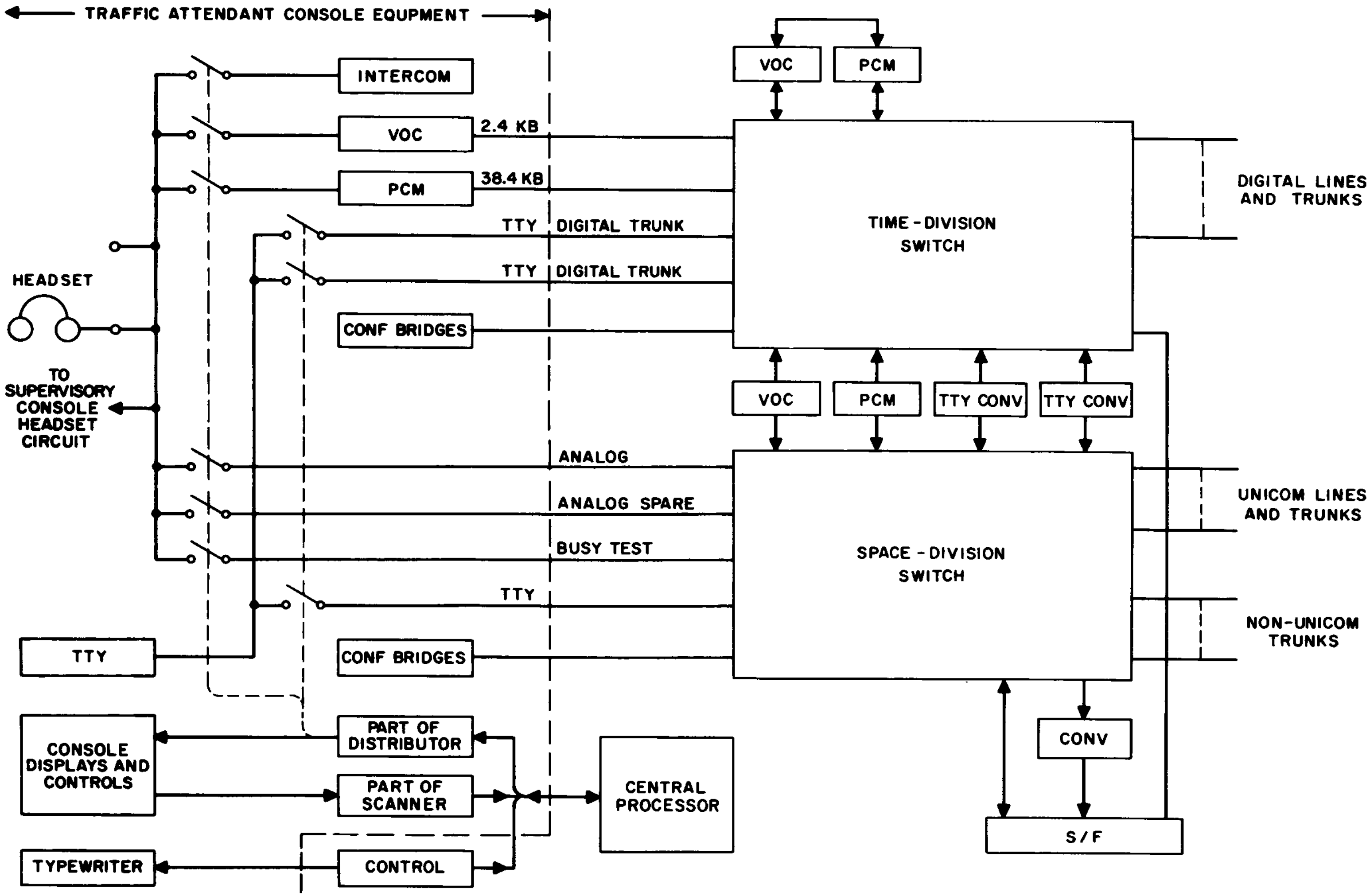


Figure 6B-1. Traffic Attendant Console

operator can only be working actively on one call at a time, a limited number of trunks from the space-division switch and time-division switch are provided. Two trunks from the time-division switch are brought to the attendant's console, a 2.4-kb vocoder trunk, and a 38.4-kb pulse-code modulation (PCM) trunk. When a subscriber calls the operator, central control will select the appropriate trunk, depending on the subscriber's bit rate. Should one of these trunks fail, the vocoder-PCM loop in the time-division switch can be used to reach the remaining good trunk. A single space-division switch trunk to the attendant console is all that is required; however, two space-division switch trunks will be provided for reliability. These digital and analog attendant trunks are essentially two-way trunks, since they are also used by the operator to originate calls. The seizure problem usually associated with two-way trunks is avoided, since the operator decides whether a call is to be received or originated.

A terminal test trunk to the console is provided. This trunk allows the operator to check whether any analog subscriber's line is busy by bridging the operator's headset across the subscriber's access terminals to the space-division switching. Two digital trunks and an analog trunk are provided for the TTY. Buffering equipment for the TTY trunks not shown on Figure 6B-1 will be provided as needed. The central control connects the appropriate trunk to the TTY when a call is originated or received. A call from a non-UNICOM system may be sent to these trunks directly if the TTY speeds and message format are compatible, otherwise special converters and the store and forward (S/F) modules will be needed to buffer the message before it is sent to the attendant's TTY.

Five voice trunk lamps are provided on the console to indicate to the operator which trunk is used for the call being handled. In addition, three TTY trunk lamps are provided to indicate the TTY trunk in use. Should the attendant wish to busy out a particular trunk because of trouble, operation of the trunk alternate action switch will inform central control not to select this trunk in setting up a connection to the operator. The switch will light red to remind the operator of a trouble condition. The key is reoperated to remove the busy out restriction.

Figure 6B-2 shows the layout of the controls and indicators on the attendant console. The arrangement of these controls and indicators is not final, since changes may be made when human engineering considerations are implemented. The use of these displays and controls is described in the following sections.

INCOMING VOICE CALL

When a digital or analog voice call is intended for the operator, the central control stores the information about this call in a call waiting file in the call store.

The central control then decides which message should be connected to the operator first if more than one call is waiting. The central control then causes the appropriate CALL WAITING lamp to light on the console, indicating the precedence of the call. When the operator decides to service this call, an attendant (ATT) key is operated on one of the unused attendant loops. When this key is operated, several actions take place.

(1) Central control selects the appropriate traffic attendant trunk.

(2) The call is switched through the network to the attendant's trunk.

(3) The VOICE TRUNK lamp lights.

(4) The ATT lamp lights.

(5) The CALL WAITING lamp is turned off.

(6) The heading information of the call is displayed on the attendant's subset lamps.

(7) The operator's headset is connected into the circuit.

(8) If more than one call is waiting for the operator, the next call to be serviced is displayed on the CALL WAITING lamps.

The operator then services the call. The operator, however, may wish to hold a routine call if a ROW CALL WAITING lamp lights. Four loops have been provided so that three calls can be held while a fourth is being serviced. If it is necessary to hold the call, the HOLD key for the loop is operated. The following actions then take place:

(1) The call is disconnected from the operator's headset and trunk, and the connection through the network is taken down.

(2) The call is held at the input to the network.

(3) The ATT lamp goes out.

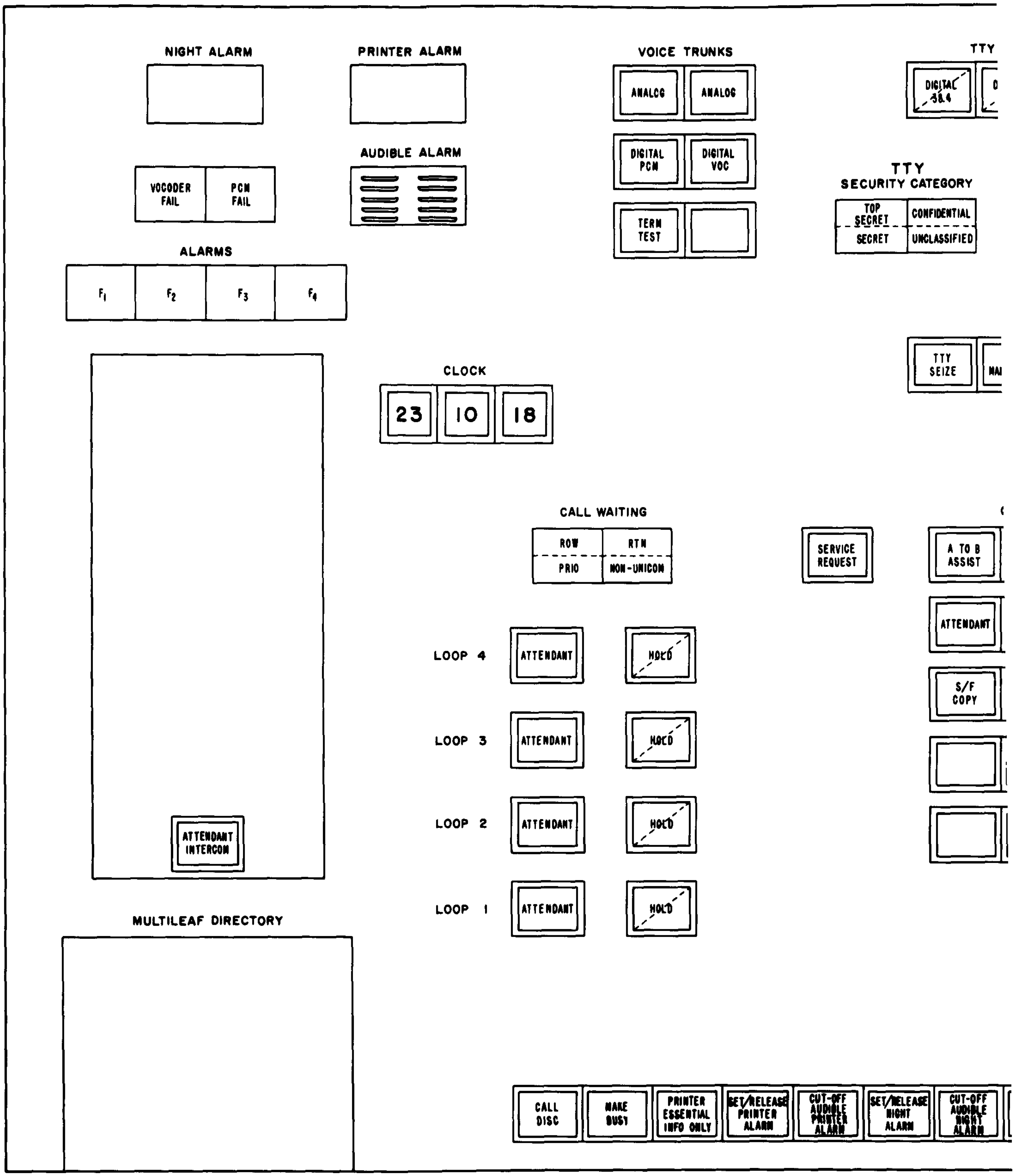
(4) The heading information on the subset lamps goes out.

(5) The HOLD lamp on the loop lights red for right-of-way (ROW) calls or white for all other calls.

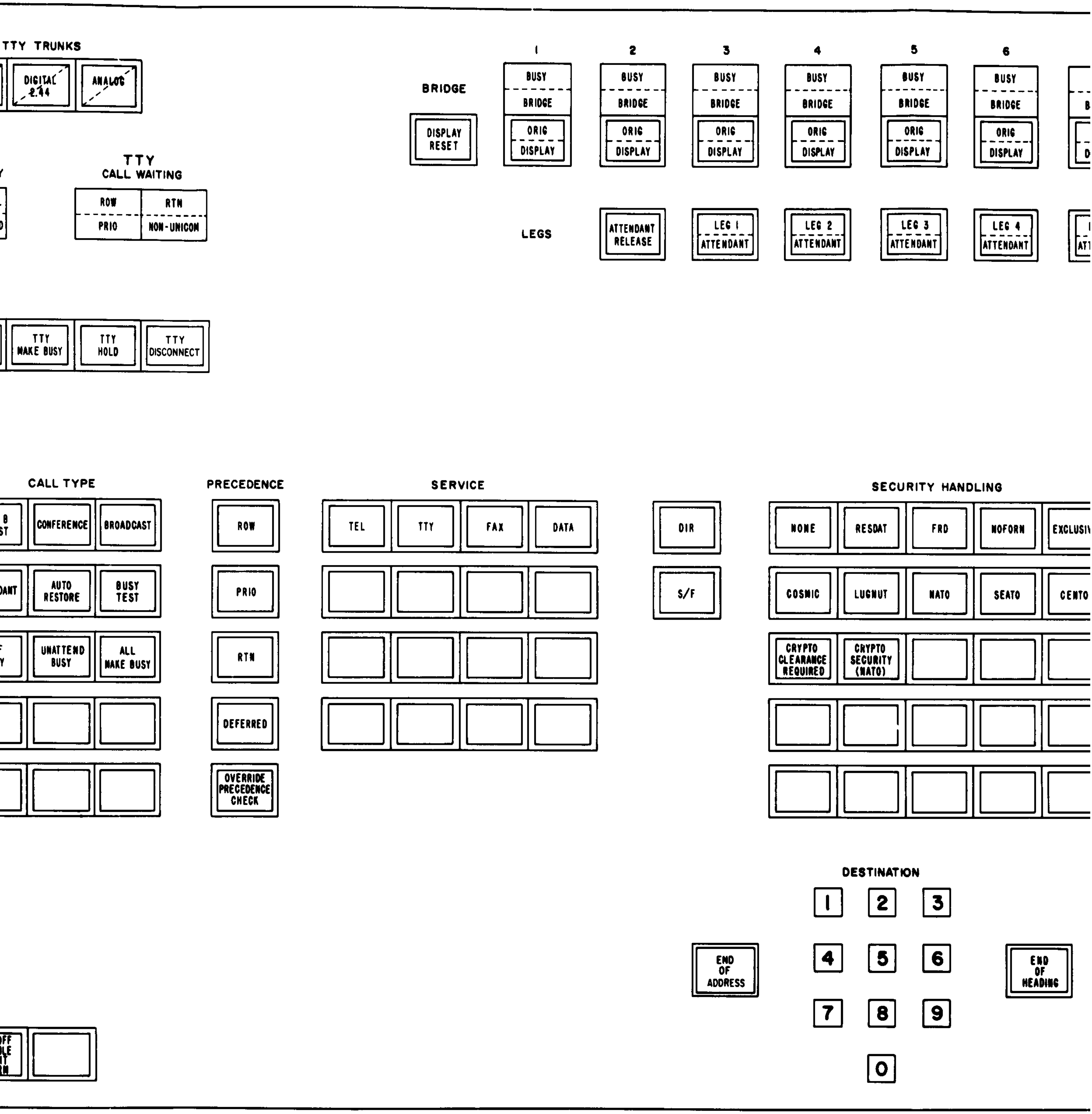
(6) If subscriber hangs up, HOLD lamp goes out.

The operator can now originate a call or service another call while the first call is being held.

When the operator wishes to recall a call being held, the ATT key is operated. The central control causes the HOLD lamp to be turned off, the call is again connected to the operator, and the heading information is displayed. When the operator


NIGHT ALARM
PRINTER ALARM
VOICE TRUNKS
TTY
ANALOG
ANALOG
DIGITAL 38.4
AUDIBLE ALARM
VOCODER FAIL
PCM FAIL
DIGITAL PCM
DIGITAL VOC
TTY SECURITY CATEGORY
TOP SECRET
CONFIDENTIAL
SECRET
UNCLASSIFIED
TERM TEST
ALARMS
F1
F2
F3
F4
TTY SEIZE
CLOCK
23
10
18
CALL WAITING
ROW
RTN
PRIO
NON-UNICOM
SERVICE REQUEST
A TO B ASSIST
ATTENDANT
LOOP 4
ATTENDANT
HOLD
S/F COPY
LOOP 3
ATTENDANT
HOLD
LOOP 2
ATTENDANT
HOLD
ATTENDANT INTERCOM
LOOP 1
ATTENDANT
HOLD
MULTILEAF DIRECTORY
CALL DISC
MAKE BUSY
PRINTER ESSENTIAL INFO ONLY
SET/RELEASE PRINTER ALARM
CUT-OFF AUDIBLE PRINTER ALARM
SET/RELEASE NIGHT ALARM
CUT-OFF AUDIBLE NIGHT ALARM

1



TTY TRUNKS
DIGITAL 2.44
ANALOG
BRIDGE
DISPLAY RESET
1
2
3
4
5
6
BUSY
BRIDGE
ORIG
DISPLAY
TTY CALL WAITING
ROW
RTN
PRIO
NON-UNICON
LEGS
ATTENDANT RELEASE
LEG 1 ATTENDANT
LEG 2 ATTENDANT
LEG 3 ATTENDANT
LEG 4 ATTENDANT
TTY MAKE BUSY
TTY HOLD
TTY DISCONNECT
CALL TYPE
CONFERENCE
BROADCAST
AUTO RESTORE
BUSY TEST
UNATTEND BUSY
ALL MAKE BUSY
PRECEDENCE
ROW
PRIO
RTN
DEFERRED
OVERRIDE PRECEDENCE CHECK
SERVICE
TEL
TTY
FAX
DATA
DIR
S/F
SECURITY HANDLING
NONE
RESDAT
FRD
NOFORN
COSMIC
LUGNUT
NATO
SEATO
CENTO
CRYPTO CLEARANCE REQUIRED
CRYPTO SECURITY (NATO)
DESTINATION
1
2
3
4
5
6
7
8
9
0
END OF ADDRESS
END OF HEADING

2

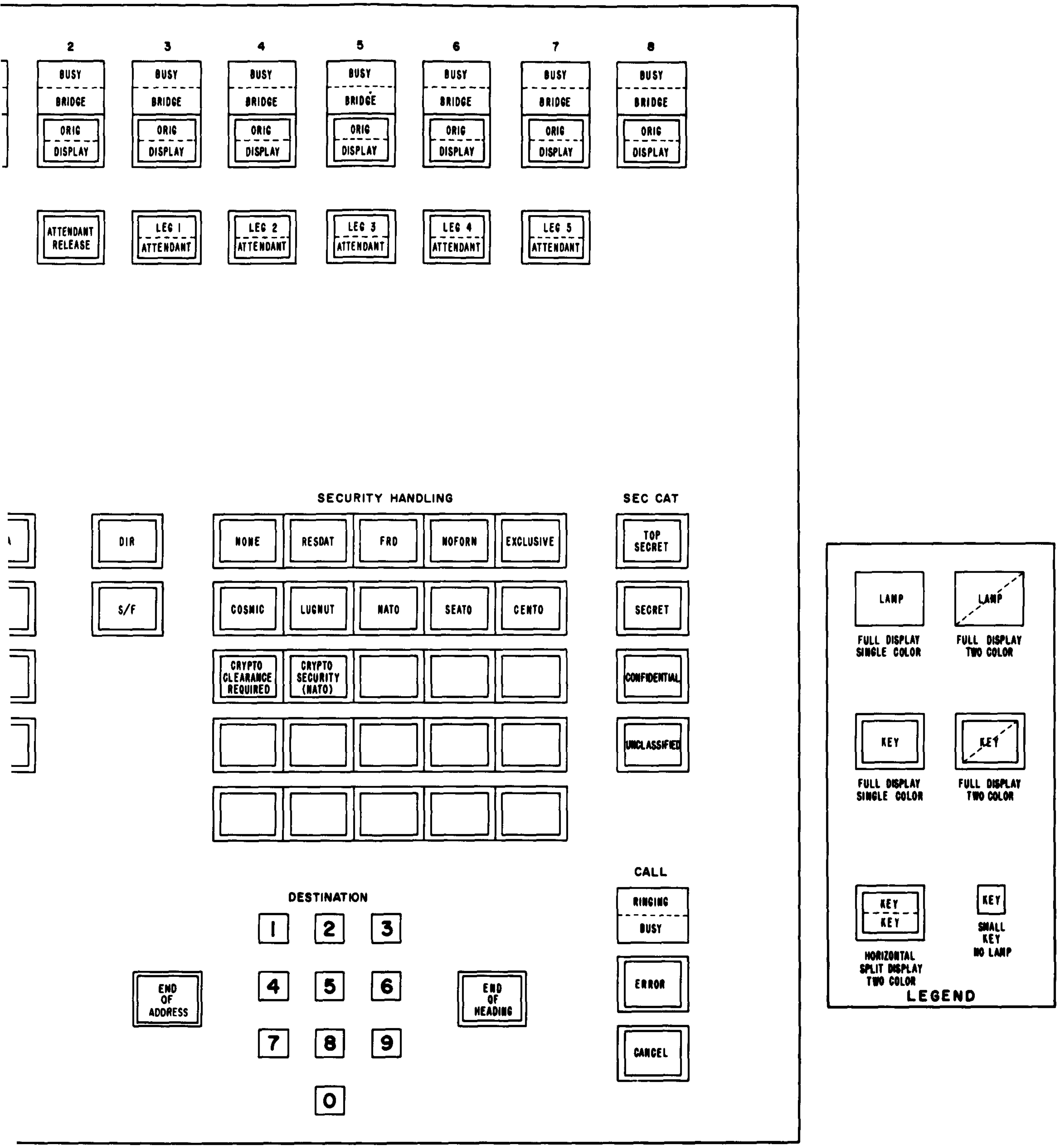


Figure 6B-2. Attendant's Position

3

wishes to hang up, the call disconnect (CALL DISC) key is operated restoring all lamps and circuits. If the subscriber hangs up first, the lamps and circuits are also restored to normal. If the operator has another call to answer, the ATT key on another loop can be operated. The central control will then disconnect the previous call if the subscriber has not already hung up, and connect the call waiting into the headset. Therefore, the operator can disconnect one call and answer another by operating the ATT key on another loop without having to first operate the CALL DISC key.

A night alarm, both visual and audible, is provided to alert the operator when a call comes into the console. This would be used when the operator is close to the console but not seated at it. The alarm is set by operating the SET NIGHT ALARM alternate action key which lights. The alarm is cut off by reoperating the SET NIGHT ALARM key. The audible night alarm is cut off by another alternate action switch.

TTY CALLS

The attendant's TTY must be able to handle messages, including classified digital messages, from both analog and digital subscribers. When a message is sent to the attendant's TTY, the central control selects the proper trunk (digital or analog) and the TTY is connected to the calling subscriber. The central control then displays the security category of the call on the TTY CALL lamps. In addition, the TTY TRUNK lamp is lighted. These displays remain lighted for the duration of the message. Should a second message for attendant TTY be originated before the first is completed, the precedence of the message is displayed on TTY CALL WAITING lamps. Once a message has been started, it will not be pre-empted by a ROW message to the operator. However, as in the case of voice calls, the central control will select the message to be delivered, based on the precedence and call waiting file if more than one message is waiting. When the message is completed, the TTY will be turned off and other messages, if any, will automatically be routed to the TTY. The above actions are completed without any control actions on the part of an operator, unless the message requires a reply.

If the operator wants to originate a call and the TTY is busy with an incoming message, the TTY SEIZE key is operated, telling central control to make the TTY available for an originating call after the present message is completed. The TTY SEIZE key lights red to remind the operator that calls to the TTY are being blocked. The attendant's subset is used to send the message heading information into central control. After the heading legality checks are made and the called party answers, the subset lamps are extinguished by central control and the precedence of the call is displayed on the call lamps. The subset is now available to make other calls if the TTY call was set up for tape transmission or for some other person in the office. The TTY will not be pre-empted by a ROW call to the operator. However, the called subscriber's TTY may be pre-empted which would interrupt the message. In this case, the TTY call lamps could go out, indicating a disconnect, and the attendant's typewriter will print the details. A TTY HOLD key is provided so the operator can hold a TTY call while the TTY is used to set up or answer another TTY call. In this case, the TTY HOLD key is operated, followed by the operation of a HOLD key on an attendant's loop. As in the case of voice calls, three TTY calls can be held while one is being worked on. It may, in many cases, be desirable to disconnect the first call and call back when ready, rather then hold a call and tie up facilities. When the attendant completes the message, the TTY SEIZE alternate action key is operated again to release the TTY and make it available again for incoming calls. A TTY MAKE BUSY key is provided to remove the TTY from service while maintenance on the equipment is performed. The key will light red when operated. This is an alternate action key and the make busy condition is removed by reoperation of the key.

A TTY DISCONNECT key is provided to allow the attendant to release the connection and make the TTY available to receive a new call or to originate a call.

ATTENDANT'S KEYSET

The attendant's keyset will allow the operator to originate both analog and digital calls. Keys which permit the operator to send all allowable preamble headings are provided. One way to implement this subset would be to modify a digital subset to include all preamble headings and special operator controls. This approach would be costly. It is planned to provide a subset which sends the information into the central control through the ferrod scanner. When a key is operated, ferrods are energized through contacts on this key. The following keys are provided on the subset.

Call-Type Keys

A call-type category has been added to the heading information. Since the operator has to assist in setting up many types of calls, the central control must be told how to handle the information that will be keyed by the operator. Many of the types of calls will be discussed in a later section when typical operating procedures for these calls are described. Nine different types of calls have been designated, leaving six spares should additional calls be found necessary.

Service Keys

The standard digital subscriber's subset will be capable of selecting any one of four ancillary devices for use in making a call. Since different subscribers may have different requirements for ancillary devices, the switching center is required to recognize and handle calls from 16 different devices with direct and S/F handling options on most of these devices. If the operator must assist in setting up all types of calls, the operator's keyset must be equipped with 16 service keys to designate the proper device and with direct and S/F keys to select the method of servicing the call.

Other Heading Keys

The standard digital subset will be provided with keys to select two security handling options. Since different subscribers have different security handling needs, the switching center will recognize a maximum of 25 security handling options. Therefore, the operator's keyset must be equipped with 25 keys to designate all of the security handling options recognized by the switching center. Keys are also provided to select the four precedence, four security category, and ten destination codes. The use of the remaining keys on the keyset will be described in the following typical operating procedure.

The operator originates a call by first pressing the SERVICE REQUEST key. When central control recognizes the service request code sent by the scanner, central control disconnects the operator's headset from the previous call being worked on. In recognition of this request to originate a call, central control will cause the key to light green. The attendant then sends in the heading information by operating appropriate preamble keys. The central control then indicates recognition of this code by causing each key to light green. The key will light within one second of the time the key is operated, as an upper limit, and under average conditions will light essentially instantaneously. The destination code is then keyed, followed by the operation of the END OF HEADING key.

The legality of the heading is checked by the switching center and if any trouble exists the ERROR key lights red. In addition, details of the error are printed out by the attendant's typewriter. If the legality of the heading is checked, the connection is established. If the called line is busy, the CALL BUSY lamp on the subset lights. If the subscriber's line is not busy, the RING lamp lights when ringing of the party starts. When the party answers, the RING lamp is extinguished and the connection is completed. When the operator has completed the call and wishes to hang up, the CALL DISC key is operated, causing central control to release the connection.

The above operating procedure is a description of a typical single address call made by the attendant. There are many alternative procedures used for special calls and special situations. If a multiple address call is made, the END OF ADDRESS key must be operated between each destination code. If it is necessary to change precedence in a multiple address call, the appropriate precedence key is operated before the destination code is keyed. If the operator makes an error in keying the destination code, the ERROR key is operated to delete the preceding destination code. If the error is not discovered until after the next destination code has been started, the attendant must operate the CANCEL key and start over. If the attendant has made an error in setting up the preamble code and it is discovered before the END OF HEADING key or the END OF ADDRESS key is operated, the correct key may be operated. The central control will recognize this as an error correction and make the change. The central control will also extinguish the lamp in the preamble group in which the change occurred.

If the operator has originated a call and wishes to hold this call in order to service a waiting ROW call, the HOLD key on one of the attendant loops is operated. When the ROW call is disposed of, the ATT key on the loop is operated to connect the first call through the network to the operator's trunk and headset. The heading information is again displayed on the keyset. Should the subscriber at any time during the conversation either hang up or be pre-empted by a ROW call, the CANCEL lamp on the operator's keyset will light. When the operator presses the CALL DISC key, the CANCEL lamp will be turned off by central control. Details of the pre-emption will be printed out by the attendant's typewriter if necessary.

OPERATOR ASSISTED CALLS

The operator must assist in setting up many types of calls. The purpose of this section is to describe briefly these special calls and to discuss possible operational procedures in setting up these calls.

A to B Assist Calls

This call is originated by the operator when one subscriber (A) has called the operator and has asked for assistance in reaching another subscriber (B). There are several ways in which this request can be handled. The operator holds the originating subscriber A on the attendant loop. The operator then calls subscriber B, using the desired preamble heading for the call. When subscriber B answers, the operator informs the subscriber that party A is waiting to talk. The operator then holds party B on another attendant's loop. The operator then causes the two parties to be connected together by originating a call in which the A to B ASSIST key is operated, followed by the destination codes for the particular attendant's loops which are holding the two subscribers. The operator will be automatically disconnected from the call when the two parties are connected, and the hold lights will go out. As with all other types of calls, the heading will be checked before the connection is made.

If the operator does not need to talk with subscriber B, the above procedure can be simplified. In this case, the attendant operates the A to B ASSIST key, followed by the preamble and destination code for subscriber B and the destination code of the loop on which subscriber A is being held. When the two parties are connected, the hold light on the loop is extinguished by central control and the operator is disconnected.

If party A does not wish to wait while the operator tries to set up the call, then a slightly different procedure is used. When the operator dials the A to B assist call, the originator's number is substituted for the loop number as described in the two preceding cases. Subscriber A's number will then be rung when party B's number is rung. This A to B assist call can also be used to set up calls to non-UNICOM trunks.

Busy Test Calls

This call is originated by the operator when a subscriber requests the operator to verify service on an analog line that the subscriber has found to be repeatedly busy. The operator presses the BUSY TEST key, followed by the called subscriber's destination code. Central control then connects the operator's headset through the terminal test access switches to the subscriber's terminals on the space-division switch. With the headset bridged across these terminals, the operator can listen to verify that the line is busy. Other records, such as line trouble reports and lists of hot lines, will also be used by the operator to handle calls which report suspected line trouble.

Automatic Restored Calls

The operator can set up allocated circuits with automatic restoral service between two subscribers. The subscriber calls the operator and requests that automatic restoral service be set up for a specific period of time. After the attendant has verified that the party is authorized to make this call, the calling party is held while the operator calls the called party. The called party is asked if he wants automatic restoral service. If the service is accepted, the attendant holds the called party on the attendant's loop. The attendant then operates the automatic restore (AUTO RESTORE) key and the appropriate preamble and destination keys. The destination keys are used to key into central control the codes of the loops on which the parties are being held and a code which designates the duration of the call. When the connection is established, the hold lights will be extinguished. Variations of the above procedure are possibly similar to those described in the A to B assist call. In place of the loop designation codes, the operator can key in the numbers of two parties involved, should one or both of the parties hang up.

S/F Copy

Should a subscriber wish to receive an S/F message which is stored on a magnetic tape in the office, the subscriber calls the operator and gives the message number and the subscriber's number. The party then hangs up since the time it takes to recall a message depends on how long ago the message was first originated. When the proper tape reel has been located and placed in S/F tape unit, the operator then sets up the call. The operator presses the S/F COPY key and the appropriate precedence and mode heading keys; the destination keys are used to key in the subscriber's number and the message number. When the heading information is checked and the call established, the subset lamps will be restored. If the operator does not want to wait until the heading check is made, the subset can be disconnected and the details of any failures to set up the connection can be sent to the operator's typewriter.

Unattended Busy

Whenever a subscriber subset is left unattended, the switching center must be notified so that any voice or classified information will not be sent to this subscriber. It is possible that a subscriber might forget to notify the office that the subset was left unattended and call the operator from another phone. In this case, the operator can make the subset busy for calls that should not be received. The operator originates a call by operating the unattended busy (UNATT BUSY) key, followed by the subscriber's destination code. Recognition of this request by central control occurs when the subset lamps are restored.

Make Busy Calls

The operator can make any line busy to all traffic by originating a call in which the ALL MAKE BUSY key is operated, followed by the subscriber's number code.

Broadcast Calls

The operator may be asked to assist in setting up a broadcast call. The operator sets up this call in the same way that the subscriber would originate a broadcast call, except that the BROADCAST key is operated instead of a repertory dialing code and the originating subscriber's number is keyed in first.

Operator Calls

When the operator wishes to originate a call to a subscriber, the ATTENDANT key is operated in addition to the appropriate preamble and destination keys.

Conference Calls

All conference calls require the assistance of the operator. Provision is made for setting up a maximum of eight simultaneous conference calls of five parties each. Each of the eight conference bridges is provided with four indicators to display status information about the bridges. A BUSY lamp is provided which lights when one or more conferees are connected to the bridge. An originator (ORIG) lamp is provided which lights when the originator is not connected to the bridge. When this lamp is on, the operator has access to the bridge and can talk with each conferee. When a conference call is being set up, the BRIDGE lamps light to indicate which bridges are selected for the call. When the BRIDGE key is operated, the DISPLAY lamp is lighted and the status of each leg on the bridge is monitored on the five LEG lamps. The LEG keys are operated to connect the attendant into each leg. The ATT lamp lights to indicate which leg is being serviced. The originator is always assigned to leg 1.

If more than five parties are involved, two or more bridges may be grouped and the originator is assigned to leg 1 of the lowest numbered bridge. A bridge in one switching center may be grouped with a bridge in another switching center to save interoffice trunks or when more than five parties are involved. This requires the use of one leg in each bridge. In the second switching center, leg 1 is used to connect the bridges. The two bridges in separate switching centers have a combined capacity of eight parties.

The following operating sequences are described for two typical calls:

(1) Subscriber calls operator, gives complete details on desired conference, and hangs up or is held by the operator.

(2) Operator presses DISPLAY RESET key.

(3) Operator keys in conference (CONF), preamble, originator's number, and other conferee's addresses.

(4) Central control makes heading checks and selects bridge or bridges to be used in the conference. BRIDGE lamps light on those bridges selected.

(5) Operator presses DISPLAY key to connect LEG lamps to the bridge. Conferees are assigned to legs 2 to 5 of bridge, in the order in which they were keyed in by the operator. LEG lamp flashes at 60 cpm to indicate parties being rung. LEG lamp flashes at 120 cpm to indicate parties busy or camp-on. When party answers, the LEG lamp becomes steady. The BUSY lamp on bridge turns on.

(6) Operator switches to each leg by pressing the ATT key. Conference tone is interrupted on that leg and the operator confirms that the desired conferee is available. The ATT key lights to remind the operator which leg is being checked.

   (a) If conferee is available, the operator requests party to stand by and conference tone is resumed when the operator switches to the next leg.

   (b) If the station answers but desired conferee is not available, the station may be requested to hang up or the operator may disconnect conferee by pressing CALL DISC key. LEG lamp is extinguished.

(7) Steps 5 and 6 are repeated if conference involves more than one bridge.

(8) Operator reports to originator.

   (a) If the originator wants to hold conference, the operator presses the leg 1 key and the DISPLAY key on the lowest numbered bridge, if more than one bridge is involved. The operator keys in the originator's address or loop number. When originator is connected into leg 1 conference, tone is removed, the ORIG lamp goes out, any ATT lamp goes out, and operator loses access to bridge while leg 1 is occupied. The BUSY lamp remains on to remind the operator that the bridge is occupied. The leg lamps continue to display the bridge as long as DISPLAY key is operated.

(9) Any conferee going on-hook causes his connection to be broken and the LEG lamp to go off. If the originator hangs up, the ORIG key lights and conference tone is connected. When all conferees hang up, the BUSY lamp goes out and the bridge is made available for other calls. The conference bridge is not automatically released when the originator hangs up because the originator may wish to add on a conferee as described in the following paragraph.

ADDING ON AN ADDITIONAL CONFEREE

(1) Originator hangs up; ORIG lamp lights.

(2) Originator calls operator on "O" operator trunk and gives subscriber's number.

(3) Operator presses DISPLAY key on the appropriate bridge, causing all BRIDGE lamps associated with the conference call to light.

(4) Operator selects and presses unused LEG key.

(5) Heading and conferee's number are keyed.

(6) Remainder of call sequence is the same as that described for a new call.

CONFERENCE CALL, TWO BRIDGES, TWO SWITCHING CENTERS

(1) Subscriber calls operator, gives complete details of conference, and hangs up.

(2) Operator 1 calls operator in switching center 2 and requests number of idle bridge in switching center 2.

(3) Operator 1 tells operator 2 details of call, including addresses that 2 must key in.

(4) Operators 1 and 2 key in preambles and addresses as for single bridge except:

   (a) Operator 1 keys in bridge address as given by 2. This address is keyed in for one of the legs. The leg 1 light comes on in switching center 2.

   (b) Operator 2 keys in a special code to connect leg 1 of his bridge to the trunk coming from the No. 1 bridge.

   (c) Operator 2 tells operator 1 that all the connections to bridge 2 have been made.

A DISPLAY RESET key is provided to restore all DISPLAY keys to normal and to disconnect the operator from the leg. This will be done before the operator makes another conference call or when the operator no longer wishes to monitor the LEG lamps. An attendant reset (ATT RESET) key is also provided to restore any ATT key on the bridge to normal. This is used when the operator wishes to switch to another bridge or when the operator wishes to disconnect from a particular leg but still retain the display of the leg. If the operator wishes to interrupt the servicing of a conference call to answer a call waiting, the operator presses the

ATT key on an ATT loop. The headset will be disconnected from the conference bridge leg and connected into the loop.

Should the operator discover that a bridge is in trouble and should not be used, the bridge can be made busy. This is done by operating the DISPLAY key on the bridge in trouble, followed by the operation of the MAKE BUSY key. The bridge BUSY lamp on the bridge will light. The MAKE BUSY condition can be removed when the trouble is fixed by reoperation of the DISPLAY key.

Non-UNICOM Calls

The UNICOM system will connect to many different military and commercial communications systems. These various systems may use different signaling methods and have different heading formats. Therefore, special equipment may be necessary to connect to these systems. Many calls will eventually be established directly by the subscriber originating the call if proper signaling converters are provided. The S/F unit may also be used to buffer any differences in data rates between UNICOM and other systems.

The traffic attendant may be requested to assist in setting up calls to these various systems. The operator will not be provided with any special signaling equipment such as a keyset or a dial to reach a non-UNICOM subscriber directly. The operator will use the attendant's keyset to send the information into central control. If, for example, the non-UNICOM office uses the same maximum usable frequency sender equipment as UNICOM, the central control can connect a sender to the proper outside trunk. The called subscriber's number can then be reached directly and the connection can be established. If the proper type of sender is not available, the UNICOM operator will use the keyset to set up a connection to the outside trunk. An operator will be alerted in the non-UNICOM office and given the called number. The UNICOM operator is informed when the called party is available. Regardless of how the called party is reached, the UNICOM operator will connect the UNICOM calling party to the outside trunk, using an A to B assist call described earlier. The above description is typical of a voice call to the Bell System. If the call was sent to a system using TTY with different information rates or signaling, the special converters and the S/F unit will be connected automatically if needed.

If a non-UNICOM subscriber wants the assistance of the UNICOM operator, the call is handled in a similar manner. If the call is voice, it will be routed to the operator's call waiting indicators like any other call. The operator will then handle this call like any other UNICOM call requiring operator assistance. If the call is TTY, the same procedure is used, except that the S/F unit and other converters will be connected in as needed.

Override Precedence Check

If a subscriber has received permission to make a call with a higher precedence than the directory allows, the attendant is called. The attendant holds the originator and keys the heading, override precedence check, originator's loop number, and called number. The heading validity checks are made, with the exception of the precedence check, and the call is connected through. A record of such calls can be kept by printing the details on the attendant's typewriter.

INTERCOM AND ALARMS

An office intercom will be provided so that the operator can talk with other personnel in the office. This intercom will not make use of the network and central control to switch to the various stations but will be an independent system. An ATT key will be provided at the console to connect the attendant's headset into the intercom. The details and technical requirements of an intercom system are now being worked out.

A printer alarm will be provided, both audible and visual, to alert the attendant when information is being printed which requires immediate operator action. A key will be provided to reset the audible printer alarm. In addition, a separate printer visual alarm acknowledge key is provided to tell central control that the alarm was recognized. An alarm lamp is also provided for the PCM and vocoders used at the console. Space is also provided for other alarms from equipments that the operator may use.

CONCLUSIONS

It is planned that the traffic attendant's console will be developed with the controls and displays as shown on Figure 6B-2. For the Test Model, only one conference bridge will be implemented; however, space and means for implementing a total of eight bridges will be provided. The actual arrangement of the controls and lamps is subject to change when human engineering studies are made.